OLD SERIES

VOLS. I - VII

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# Engineering Society.

1885-6.

## School of Practical Science,

PROVINCE OF ONTARIO.

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1887.

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# PREFACE.

The Engineering Society of the School of Practical Science was founded in the spring of 1885, through the exertions of a few of the students in the Department of Engineering. Messrs. Herbert Bowman of the third year, and T. Kennard Thomson of the second year, being the principal promoters. Meetings are held every second Tuesday during the session, at which papers are read and engineering questions discussed. In order to keep alive the interest of graduates in the success of the Society, it has been decided to publish annually some of the leading papers contributed during the previous session. The following papers have been selected for publication from among those which had been read up till the end of the academic session, 1885-6. The guiding principle in making the present selection may be briefly explained. In the papers read at the society's meetings originality is not considered a necessary condition. The main object of the paper is served if it furnishes the society with food for discussion, and the writer with experience in the collection of information, and in expressing his ideas with clearness and precision. To make originalty in matter *sine qua non* would practically do harm instead of good. The majority of the writers are students, the greater part of whose time is necessarily spent in acquiring information already in possession of the profession, and who can ill afford to spend much of it in attempting original work. While this is true, it was yet felt by the publication committee that it would be useless to publish papers, the information in which had been gathered chiefly by reading. No paper, therefore, has been printed in the present selection the writer of which has not had some experience in the subject dealt with.

It is hoped by the general committee of the society, that graduates of the School and former students who are now engaged in active work, will make endeavors to contribute papers relating to their work to be read at meetings of the society.

If the present venture be financially supported by former and present members of the society, it will be followed next year by a similar selection from the papers contributed during the session 1886-7.

In order to keep faith with the gentlemen who have contributed advertisements, an edition of five hundred copies has been printed, which will be widely distributed among Engineers and Surveyors.

The following is a complete list of all the papers which have been read before the society from its foundation up till the end of the session 1885-86.

1884-5.

| | |
|---|---|
| Railway Curves | *B. A. Ludgate.* |
| Transition Curves | *J Allison.* |
| Surveying in the North-West | *E. B. Herman, D.& P.L.S.* |
| Surveying | *H. Bowman.* |
| Surveying in Ontario | *W. O. Johnson.* |

1885-86.

| | |
|---|---|
| A System of Survey in British Columbia | *A. M. Bowman.* |
| Picketing a Straight Line through the Bush | *C. H. Pinhey.* |
| Notes on Railroad Construction | *E. W. Stern.* |
| Asphalt Pavements | *E. F. Ball.* |
| A Re-Survey in Ontario | *A. E. Lott.* |
| Angle Blocks for Howe Trusses | *T. K. Thomson.* |
| Explorations of the Battle River | *H. G. Tyrrell.* |
| Mortars and Cements | *A. L. McCulloch.* |
| Cross Sectioning | *W. F. Tye.* |
| Determination of Strains in a Truss | *C. H. C. Wright.* |
| Requisites of Camp Life in the North-West | *F. Martin.* |
| Electric Blasting | *J. N. Smith.* |
| An Improvement for the Theodolite | *B. A. Ludgate.* |
| Disposal of Sewage | *R. Laird.* |

# NOTES

## ON THE

# FIELD WORK OF RAILROAD CONSTRUCTION.

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## E. W. STERN.

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In treating of this subject, the writer will deal chiefly with the work an Assistant Engineer will be obliged to do on railroad construction, merely pointing out that before the contractors come upon the ground, explorations, preliminary surveys, and finally the location, will already have been made, plans and profiles got out, and all the information gained in these surveys made use of to find the approximate cost of the building of the road, upon the strength of which, money is raised to cover the cost of construction.

Assuming all this done, the construction staff is then placed in the field. The Chief Engineer, who generally has his headquarters at the main offices of the company, has under him several Division or Resident Engineers, who supervise the construction of thirty or forty miles, and who take up their residence at some convenient point close to the centre of their division. Under each of these are three or four assistants, or Section Engineers, who have charge of ten miles or so, and who undertake all the instrumental work, such as cross sectioning, estimates, alignment of track, etc. Each assistant has usually two or three men—a roadman and two axemen. He is generally furnished with an office by the company, and this should, as nearly as possible, be in the centre of his section. We will suppose now that the assistant has been put in charge, and the contractors are on the ground ready to begin work. The first thing to be done is the clearing. This should be staked out by placing stout stakes about 5 ft. long, and blazed on three sides, opposite each station, at the limit of the right-of way, usually 30 or 50 ft. from the centre line, at the same time he should furnish the contractors with a note stating when *close-cutting* and *grubbing* will have to be done, as both these operations are much more easily performed while the clearing is going on, and the tree is standing. This information can readily be gained by inspecting the profile.

Close-Cutting (the cutting down of the tree close to the ground) is necessary where embankments are low, usually four feet and under.

Grubbing (pulling out of the tree by the roots) where the bank is so low that close cutting will not be sufficient. Grubbing is also allowed in low cuttings from 4-2 feet and under.

Slashing should be done at the same time as the clearing. It consists in cutting down all decayed or leaning trees outside the right-of-way allowance, which, if they fall, would fall across the track or break down the fence.

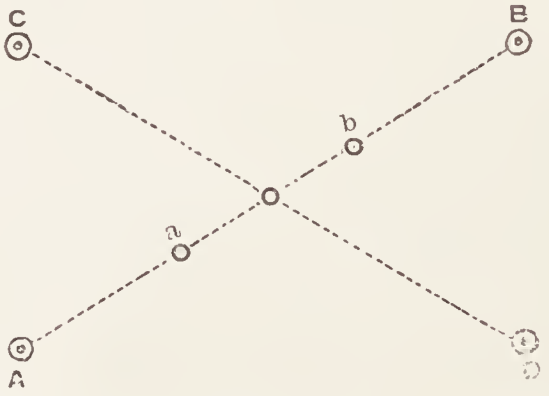
After the clearing, slashing, grubbing, and close-cutting have been done the contractor is ready to commence his earth-work, which must be cross sectioned and staked out beforehand. Before doing this the assistant will require to rerun in the centre line. On the location this is very often done carelessly, and moreover stakes may have been burnt out during the clearing. There should be a stake every 100 ft., and on deep, irregular cuttings, especially on curves, at 50 ft. or even at every 25 ft. Very often on tangents, especially over broken ground, the hubs (*i.e.* points, where, on the location the transit has been set up) which are stout chunks of wood driven into the ground with a tack put in to designate the point are found to be not quite in line. The tacks should be moved over into their correct positions; the same should be done to the " Points on Curves."

Hubs at the beginning, middle, and end of curves, as well as intermediates on long tangents, should be well referenced in, and extra points in the vicinity of important pieces of work such as trestles, culverts, deep cuts, etc., should be put in and referenced.

The most usual, as well as the most exact way of doing this, is by the method of intersections, as follows :—

The transit is set up over the point, say B. C. 2419+21, a stump a little inside the edge of the right-of-way chosen, a blaze cut on the face of it, and marked *Ref. Point B. C. 2419+21*, a notch cut in one of the roots and a tack inserted. This being used as a back point, the instrument after being set on it, is reversed, and a point put on another stump if it happens to be in line, or if not, on a hub driven in flush with the ground and marked by a post three feet long, driven well into the ground. The transit is then turned in another direction, nearly at right angles to its former position, and two other points thus placed. Stumps of trees are the best references for points, and should always be chosen when possible. The bearings of each of these lines should be noted. They are useful in finding the hub if the post be knocked out.

In putting in a point from these Reference Hubs, the reverse operation is performed.



Suppose A. B. and C. D. to be the Reference Points. Set up at A. and fix the transit on B.

Now at about two feet on each side of where you think the centre will be, put in two temporary stakes, *a. b.*, leaving them about 6 in. above the ground, and put a tack in each on line, about one-half sticking out. Stretch a thread from *a.* to *b.*, then set up at C., and after clamping on D., line up a picket held truly plumb, keeping it close against the thread *a. b.* The point is thus found.

Occasionally slight mistakes are made on curves during location. The angle of intersection of the tangents should always be checked, and the error, if any, distributed equally around the curve. A two degree curve may thus be made out of a 2°, 01′, or a 1°, 59½′.

Before cross sectioning, check levels should be run across swamps, and such places, where Bench Marks, even if put on stumps, may alter in elevation owing to the ground rising and falling ; the writer has found a difference of 0.7 feet in a case where the Bench had been placed but two months before.

A considerable number of forms for cross section books for the field have been recommended by different authors. The subjoined one, although not different in theory from some that have been published, will be found much more compact.

LEFT PAGE. RIGHT PAGE.

| ℄ Sta. | B. S. | I. S. | F. S. | Elev. | H. I. | Elev. S. G'de | CROSS SECTIONS. Left. | CROSS SECTIONS. Centre. | CROSS SECTIONS. Right. |
|---|---|---|---|---|---|---|---|---|---|
| B.M. | 2.13 | | | 453.00 | 455.13 | level | 40′ left 2436 on | | Tam Stump. |
| 2434 | | | | | | 25.1<br>430.00 | $\underline{11\cdot1}=\left(+\frac{14\cdot0}{32\cdot0}\right)\ \frac{7\cdot3}{11}$ | 4 3= +20.8 | $\frac{2\cdot9}{11}\ \underline{\qquad 1\cdot1}=\left(+\frac{24\cdot0}{43\cdot5}\right)$ |
| +50 | | | | | | 25.4<br>429.70 | $\underline{11\cdot5}=\left(+\frac{7\cdot6}{22\cdot4}\right)\frac{11\cdot9}{11}$ | 9.0 = +16.1 | $\frac{6\cdot9}{11}\ \underline{\qquad 1\cdot8}=\left(+\frac{23\cdot6}{46\cdot4}\right)$ |
| T.P. | 1.30 | | 14.62 | 440.51 | 441.81 | 1.00 | | | |
| 2433 | | | | | | 12.8<br>429.0 | $\underline{2\cdot6}=\left(+\frac{10\cdot2}{22\cdot8}\right)\ \frac{3\cdot0}{11}$ | 3.0 = +9.8 | $\frac{3\cdot2}{11}\ \underline{\qquad 3\cdot4}=\left(+\frac{9\cdot4}{21\cdot6}\right)$ |

In the column marked ELEV OF SUB-GRADE, is copied from the profile the elevation of formation level at the respective stations, as well as the grades and the places where they change, *e.g.* at Station 2434, the elevation of sub-grade is 430.00, and from this point northwards the grade falls 1.00 foot per 100 feet, *i.e.* a 1.00 grade. While southwards the grade is a level one. The reference point denoting that the grade changes at 2434.

Suppose now we are ready to cross section. The rod is held on a B. M., it reads 2.13 say—and the elevation of Bench is 453.00. H. I.=455.13. Then 455.13=430.00—25.1, and is the distance the grade line at 2434 is below the line of collimation of the instrument. This is called the "grade rod," in other words it is the reading the rod will require to have if its bottom is at grade elevation. The "grade rod" at this station 25.1, should be marked in small figures above the sub-grade elevation 430.00. The rodman now holds his rod at the centre peg at station 2434—it reads 4.3 feet. Put this down in the centre column of the cross section page, and immediately find the cut by subtracting it from 25.1. Thus—25.1 – 4.3=20.8.

This should be noted as follows :—4.3=+20.8, which interpreted means simply, a reading of 4.3 on the rods gives a cut of 20.8 feet.

This is then marked on the stake in plain, neat figures, with a piece of red chalk.

The rodman next holds his rod at the distance of the edge of road bed, which in this case is 11 feet from the centre, and a reading 7.3 is taken and entered $\frac{7\cdot3}{11}$ in the note book. Since we don't require to use the reduced cut at this point just now, we need not make the reduction until we get to the office. The rodman next feels for the slope distance. We find that a reading of 11.1= + 24 feet gives the position of the slope stake=32 feet, this is noted thus $\underline{11\cdot1}=+\frac{14\cdot0}{32\cdot0}$. A stout stake 1½ inches square, and about two feet long, should be driven down firmly at this point, and on one side marked the station number 2434, and on the other the slope distance, thus, S 32.0.

It will be observed that in this system of note taking, every reading made in the field, and every operation performed is noted, so that at any time the reductions made, when a new G. P. is used, or the cuts and fills marked, may be checked.

The cross sections taken from day to day are entered in the field book as they occur, and there need be no especial pains taken to keep them continuous, since the contents of the book should be indexed ; and, moreover, the cross sections should be copied every evening into what is called the "office copy," a separate book kept for the purpose.

These notes may be entered in ink, and the stations should be in continuous order. A convenient form of book is as follows, the left hand page being used for the cross sections, the right hand for quantities and remarks, such as positions of bench marks, notes of beginning of curves, etc., **E.** C.'s, Ref. Points, etc., and any information that may be useful.

| | CROSS SECTIONS. | | | | | | CUTS. | | FILLS. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sta. | Left. | | Centre | Right. | | Elev. Grade | Area. | C. Yds. | Area. | C. Yds. | Remarks. |
| 2434 | +14.0<br>32. | +17.8<br>11 | +20.8 | +22.2<br>11 | +24.0<br>43.5 | level<br>430.00 | 936.45 | | | | B.M. 40'E 2436<br>on Tam St.<br>El.=453.00. |
| +50 | +17.8<br>22.4 | +13.5<br>11 | +16.1 | +18.5<br>11 | +23.6<br>46.4 | 0.60 | 757.50 | 1624.0 | | | |
| 2433 | +10.2<br>22.8 | + 9.8<br>11 | + 9.8 | + 8.6<br>11 | + 9.4<br>21.6 | 429.00 | 312.40 | 990.6 | | | |

A very common way, in fact the most usual way, of calculating the quanties in the cuts and fills, is by averaging the end areas.

This method has been used in the above example.

A great convenience when one is setting slope stakes, is to have a table of slope distances written out in the back of his book, giving the distance of the slope stake out from the centre for cuts or fills, for every tenth of a foot. A convenient form is here given.

CUTS, WIDTH 22 FEET.

| Feet. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 11.0 | 11.2 | 11.3 | 11.5 | 11.6 | 11.8 | 11.9 | 12.1 | 12.2 | 12.4 |
| 1 | 12.5 | 12.7 | 12.8 | 12.9 | 13.1 | 13.3 | 13.4 | 13.6 | 13.7 | 13.9 |
| 2 | 14.0 | 14.2 | 14.3 | 14.5 | 14.6 | 14.8 | 14.9 | 15.1 | 15.2 | 15.4 |
| 3 | 15.5 | 15.7 | 15.8 | 15.9 | 16.1 | 16.3 | 16.4 | 16.6 | 16.7 | 16.9 |

After the first two columns have been computed the remainder can be interpolated. Since a difference in height of 2 feet=a difference of slope distance of 3 feet, for finding the distance for the depths 2.0, 2.1, etc., add 3 feet to each of the figures in the first line respectively, and for 3.0, 3.1, etc., add 3 feet to each in the second line.

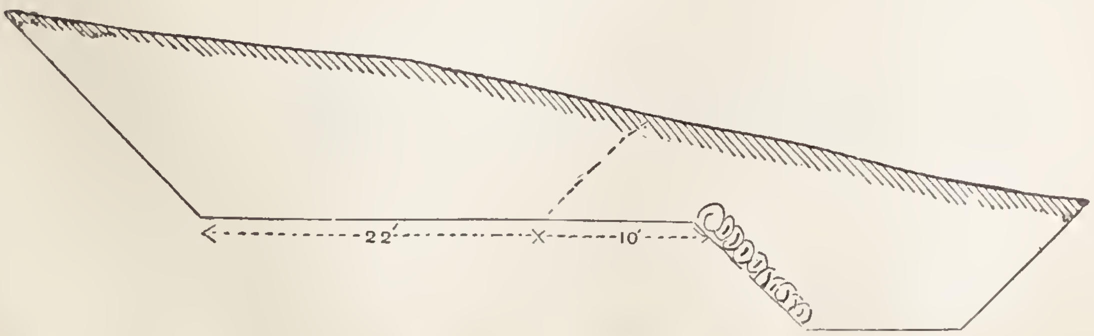
This little table, which should be worked out to a depth of 35 ft. will (with another for embankments) be found very useful, both in saving a great deal of time in the field and in preventing mistakes.

The cross sections are plotted generally on a scale of 20 ft to the inch. The measurements should be all marked on them as well as the area of each section, and the number of cubic yards between each pair. As construction is rushed very much now-a-days, and as the quantities are generally calculated from the excavation measurements, it is usual to plot only the cuts.

Before the grading has been commenced, the Division and sometimes the Section Engineer travel over the work and thoroughly examine into the way the road-bed is to be drained and kept dry. Creeks may have to be diverted where the road-bed follows the course of a winding one, ditches dug on either or one side of it, bridges or trestles built. He must ascertain as well as possible from the settlers or inhabitants, or from his own observation, what body of water may be expected at the time of greatest flood. He also ascertains what sort of foundations there are to be had where structures have to be built, and decides upon what style of structure is suitable for the different places. This information is embodied in a report and sent to the Chief Engineer, who designs his structures accordingly. The common way of testing for foundations is by means of "sounding" rods These are long iron rods about ¾ in. thick, and 8 or 10 ft. long, arranged so as to screw together into a continuous length of 40 ft. or more. The first length (which has a pointed end) is held vertically and pushed into the ground by two men, lifted up a little and pushed in again. When it has sunk sufficiently a new length is added, and the operation continued until sound bottom is reached, when the rod can't be sunk further. If rock is reached the rod gives the hand a sharp jar.

Sometimes a stratum of hard material occurs, under which there is a bed of quick-sand. To discover this, the ramming should always be persisted in for some time after good bottom is reached. Sounding rods cannot well be used on dry ground, then pits should be dug, and these will shew clearly what sort of foundation is to be had.

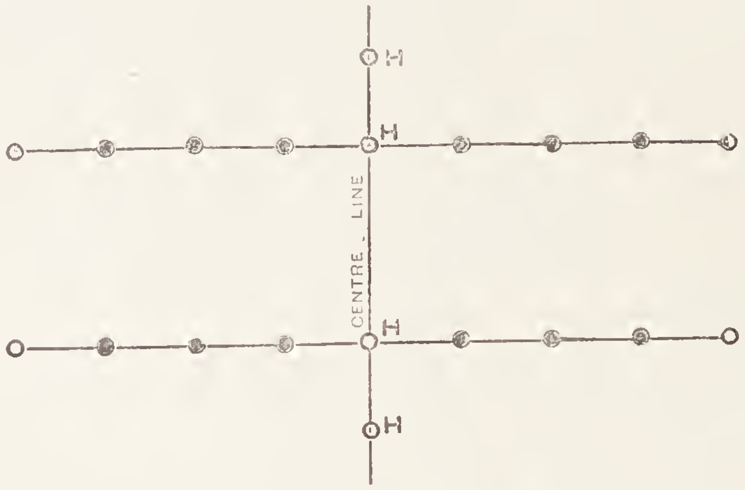
Very often, especially in a difficult country, the line follows a river or creek bed, which crosses and recrosses it several times. By cutting a new channel, as in sketch, very often a number of trestles can be cut out, which means a great saving to the railroad company. Small creeks crossing the line may be diverted down side ditches into larger ones, where culverts have been built to provide a crossing. The ground should always be most thoroughly examined to see if these divisions cannot be made, as time thus spent is not thrown away. These divisions should be cross sectioned and staked out much in the same manner as a line cut, an ample berme of 10 ft. or more being left between the edge of road-bed and creek, thus :—



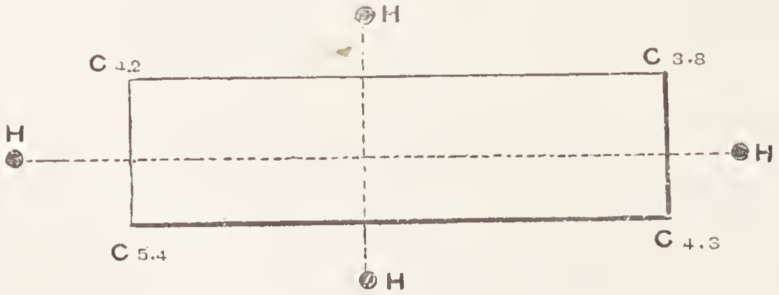
Very often rip-rap has to be thrown in along the bank in these places to protect it.

## LAYING OUT PILING, CULVERTS, FOUNDATIONS, TRESTLES, Etc.

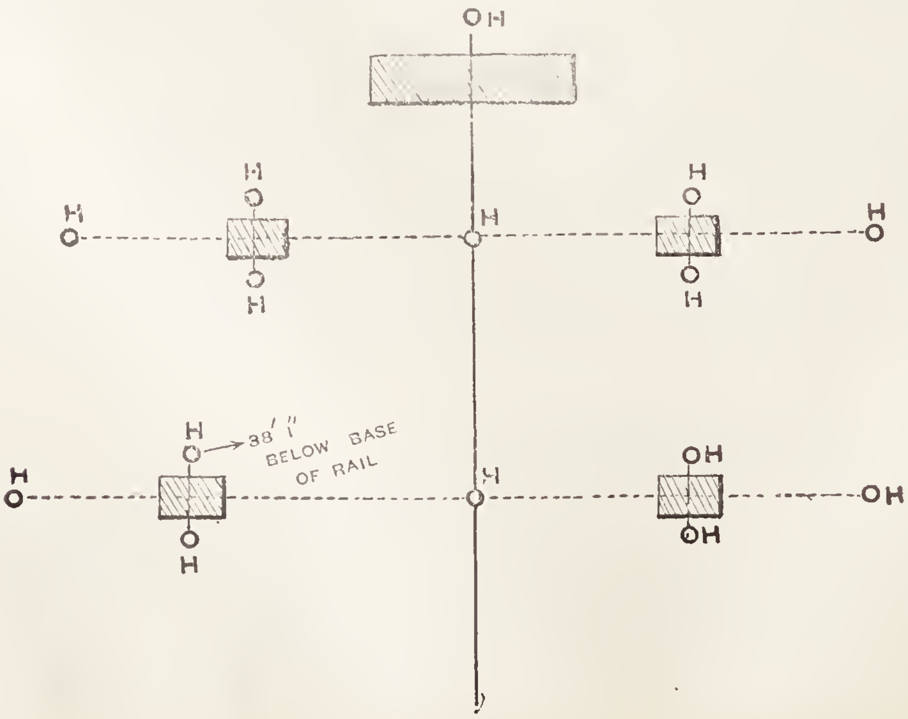
Where culverts have to be built upon treacherous ground, piling becomes necessary. The plans sent from the head office shew the disposition of the piles, and the assistant must lay them out accordingly upon the ground. Hubs must be put in on the centre of each bent, and two others at right angles, and some distance out, so that they will not become disturbed by the operation of pile driving. The foreman in charge of the driving should be furnished with the distances at which the piles are to be spaced.



Usually have a stake at each corner on which the depth of cutting is marked. Hubs are placed as at " H " on the centre line, and at right angles to the centre of the pit.



Masonry work such as the abutments of a bridge, or pedestals of a viaduct are laid out as follows :—The distance along the centre line between the centres of each bent is very carefully measured out on the ground with a

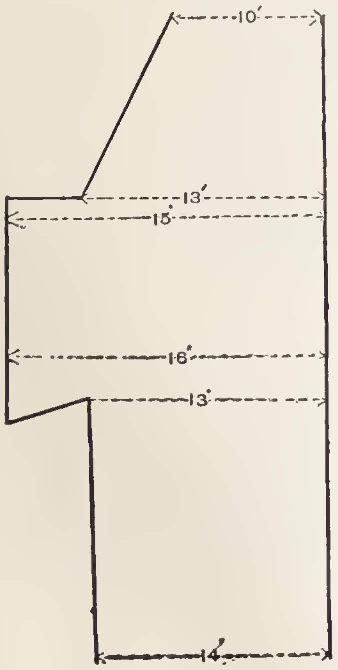


steel tape, and hubs put in with the tack precisely lined up with the transit, at these points. After these have been laid out, a thin steel wire is stretched from one end to the other, the difference of elevation of its ends noted by means of the level, and small marks made on the wire over each hub. It is then measured with a steel tape, and the distances reduced to the horizontal. A very effective check is thus obtained. At each of these hubs the transit is set up and right angle hubs put in as in the figure. The distance to the centre of the pins, taken from the plan, is measured along these, and hubs at right angles to these axial lines put in. The depth below base of rail or below top of coping stone, is also marked on one hub of each set. When the masonry has been brought nearly up to the right height, distances and heights should again be given to the foreman. The elevation of the bottom of the masonry as well as its size should be noted immediately it is started so as to be able finally to work out the quantities in each pair, which of course can't be done after it is finished and the earth filled in.

Culverts are laid out in much the same way as masonry. After they are built they should be watched carefully to ascertain whether there is any scour at either end. If there is, a couple of cart loads of rip-rap spread over the channel at the ends will effectually stop this.

## ESTIMATES, Etc.

About the 27th of the month the assistant must start to take his monthly measurements for the estimate which consists in making a return of all the work done up to date on his section. He should commence at the bottom end of his work and go over the whole of it, noting what clearing, slashing, close cutting, grubbing, earthwork, rockwork, masonry, timberwork, etc., may have been done in a book kept especially for the purpose. About the most troublesome work to keep track of is ditching and side borrow. It is the easiest work to do, and for this reason it is generally sub-let out into small contracts of usually 100 ft. or so, hence the term applied to it—"Station Work." The writer thinks that by adopting the following method of keeping the notes, much confusion will be avoided. Use the centre line as a base for measurements, take sections every 100ft., or less if the ditch demands it, noting most carefully what pieces have been finished, so that they need not be gone over again. The measurements of these finished ditches should be transferred at once to another book in continuous order, space being left for what is not yet finished. The following shews the method of noting a piece of ditch work.



| Rem'ks | Sta. | Dimensions. | Area. | C. Yds. |
|---|---|---|---|---|
| Finished. Costello & Co. | 2400 | 14+3.8 | | |
| | +80 | 13+3.8 | | |
| | +80 | 16+3.8 | | |
| | 2401 | 16+3.6 | | |
| | +40 | 15+3.7 | | |
| | +40 | 13+3.7 | | |
| | 2402 | 10+3.0 | | |

A line drawn after a station number indicates that the ditch ends there.

## LINE CUTS.

If line cuts are taken out down to grade with a face, they are very easily measured, finding the stations between which it is finished and working out the quantities from the original cross sections being all that is necessary ; but when worked from the top irregularly they are more troublesome, and the level may have to be used to get at the quantities.

The number of men a contractor has working for him should be noted several times during the month, as this affords a good rough check on the estimates. For unfinished work the estimate should be rather under than over the true amount, the aim being merely to put enough funds into the hands of the contractors to pay his men.

The computations should be worked out by the assistant and the roadman together, so as to check one another. While the office work is going on the axemen may be employed in making stakes at convenient points along the line Forms are provided for recording the monthly progress estimates in detail, there being a heading for each article mentioned in the schedule; other forms are supplied on which the estimate is put down in a more compact form, and sent to the resident Engineer, who examines them, fixes the prices, and forwards them to the Chief. The latter signs them and orders the amount to be paid out to the contractor.

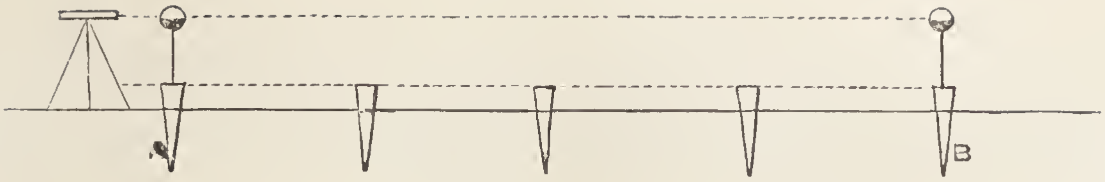
## CENTRES AND GRADES.

When the grading is about being completed the assistant requires to go over the work and put in centre and grade pegs, according to which the contractor should be required to time his work up. These stakes if they are stout and well driven down will do for track centres, though a great many will require to be put in again, the distributing of ties and bridge timber by teams, etc., being fatal to them. When the grading has been finished, the ties are distributed along the line preparatory to being put under the rails. Now is the time to run in the track centres, these can be put in without using the transit from the slope stakes, and from the old centres, curves may be put in with the tape by chord deflections. After the track is laid, the ballast is put on in two or more lifts. Before the final lift is made the centres have to be run again most carefully over the whole line, stout stakes 2 in. square being driven down firmly every 200 ft. on tangents, and every 100 ft. or 50 ft. on curves, and a track placed exactly on line on each stake.

To run in a tangent 3 or 4 miles long, set up a very large picket at one end with a white flag on it. Set up the transit at the other end and run towards this picket, moving the instrument every twelve or fifteen hundred feet to keep up with the chainman.

## BALLAST PEGS.

On the inside of curves opposite each centre stake, and on tangents, there should be a stout stake driven down at the end of the tie, so that its top shall be level with the *top of rail* when the ballast has been brought up to the required level. The following method of setting ballast pegs is to be recommended, both for its rapidity and accuracy :—



Set ballast pegs along the line at intervals of 2,000 feet or so, with the level in the ordinary way, also at the points where the grade changes, (where vertical curves have to be run in). Now to put in intermediates at 200 feet or so; set up the transit nearly, but not quite, over one of these points thus placed as at A. Place a target rod (the assistant can make one readily himself, it need not be longer than 5 feet) upon A.; lower or raise the sliding part until the centre of the target is on a level with the horizontal line of the transit. Now have the rod so adjusted, held at B.; set the horizontal thread of the instrument on the target, and clamp the axis of the telescope. Grade pegs are now readily set by driving a peg in, leaving it a little too high, holding the rod alongside and moving it up and down, till the centre of the target coincides with line of collimation. The rodman is motioned "all right." He then makes a mark on the stake at the bottom of the rod, and by means of a hand-saw, which he should carry, cuts it off. The top of the stake is, of course, on the grade line, A. B. In this manner a great deal more pegs can be set in a day, than by the old method, with just as great if not greater accuracy. The pegs are put on the inside of curve, because the outside rail has to be elevated according to the degree of curvature, which is generally one-half a tenth of a foot for every degree of curvature. This being the correct elevation for a speed of about thirty miles per hour. The "lifting gang" generally do this themselves, the foreman being furnished with a list of elevations, reduced to inches, for different curves. At all B. C.'s and E. C.'s, a stout post, 3 ft. long and 3 in. square, should be well driven down, and on it marked the Station number and the degree of the curve. This serves as a guide both to the liners and lifters.

## INSTRUMENTS.

A great deal of walking has to be done when the construction is first under way, and in some countries where there are no roads fit to drive a buckboard over, this must of necessity be the only means of progression, until the welcome hand car makes its appearance.

Lightness of instruments is, therefore, an essential. If one has a transit with a good level tube on the telescope, he may often leave his dumpy or Y level at camp, a consideration worthy of notice.

According to the writer's experience, an American transit, though not so durably constructed as one of English make, and not finished as well, is by long odds the most handy instrument in the field, and saves a considerable amount of time. If an instrument were constructed with the English form of standards, telescope, and general finish, combined with the American form of tripod, shifting centre, leveling and tangent screws, divided circle, and compass, the result would be one which, for all ordinary purposes, would be practically perfect.

## LEVELS.

For ordinary railroad work the dumpy, from its lightness and from the permanency of its adjustments, is to be preferred to the Y levels. Of course, for important structures, such as bridges and viaducts, the Y, from being susceptible of closer adjustment, is to be preferred.

## SWELLING RODS.

For cross sectioning a single slab of wood shod with iron, 14 ft. long, 3 in. x $1\frac{1}{2}$ in. at the bottom, and 2 in. x 1 in. at top, painted white, and divided into feet and half tenths, will be found much more handy and useful than a telescope rod. With a little practice $\frac{1}{100}$ ft. can be estimated with the greatest precision. A rod of this kind can be got up very cheaply.

## TAPES.

Tapes used for cross sectioning should be in feet and tenths; computations being much more easily made than when in feet and inches.

# A SYSTEM OF SURVEY
## — IN —
# BRITISH COLUMBIA.

A. M. BOWMAN.

The survey with which we were connected in British Columbia consisted chiefly of exploratory work. The main object was to obtain the best, most extensive, and most complete geographical information in the shortest time; and from the methods used, you will see that the information, though not so precise, was still obtained with a considerable degree of accuracy.

Our instructions were to procure topographical and geological notes of the country passed through, to note the kinds of timber and quality of the soil, and also to shew the boundaries between the different geological formations. Barometrical readings of both mercurial and aneroid barometers were also required to be taken. It was also necessary to state the character of the weather each day, and to gather botanical as well as geological specimens.

The kind of country surveyed was generally rugged and mountainous, and on the coast was well timbered. In the interior, however, timber was not so plentiful. It existed principally in the higher altitudes, the valleys being covered with what is known as bunch grass, and hence afforded excellent facilities for cattle grazing. Above a certain altitude no timber exists, The country is here and there dotted with mountain peaks, which may be seen one from the other, and the surveyor is thus enabled to carry on a system of triangulation by means of which he can check his work and make a more connected and exact survey.

Before going into new and unsettled quarters, the surveyor endeavors to procure from the old Indian hunters and trappers all the information possible regarding their trails, and the large streams in the district. If there are large streams and lakes he may travel by canoe into the country, but if not he provides himself with horses and axemen, and tries as much as possible to follow the Indian trails. A knowledge on the part of the surveyor of how to get through an almost impenetrable country with the least expense is one of the most important considerations in the eyes of the government in making their appointments.

The instruments used are a mountain transit, a sextant, a prismatic and a pocket compass, a hand level, also mecurial and aneroid barometers. A micrometer may also be conveniently used in measuring the distances across small lakes. The transit which has a vertical circle attached to it is principally used upon the summits of high mountains, to measure the exact angles between all prominent peaks, and also their angular elevations or depression above or below your horizon. This instrument has one of "Gurley's Solar

Attachments" which enables the surveyor to obtain the true meridian from the sun any time during the day.

The prismatic compass is used in taking bearings to mountains, only a short distance away, and also in ascertaining the general course of our trail, while the pocket compass is used in obtaining the smaller bends and windings of the course. The hand-level is used in connection with the prismatic compass to determine the angular elevation or depression of the object sighted upon with the compass.

In this work the distances are all estimated with a few exceptions, viz :—those obtained by the micrometer.

In travelling through the country the rate of travel is estimated, and the interval of time being known, our distance may be calculated, the result of which becomes a very close approximation to the true distance. In travelling in a canoe the average rate is about a 6 gait, and that of a pack-horse about a 4 gait.

The pocket compass, as was before stated, is used in making the track survey. This however is not sufficient to give us the true bearings of our course. By a judicious use of the prismatic compass a very admirable check upon the pocket compass is attained. It is done as follows :—Suppose we are travelling up a river valley having small mountain peaks on each side, we take bearings to each of these, at the same time, estimating their distances and noting their positions in our track survey sketch, but for the purpose of checking the survey, we must take at least three sights to the same point from different positions in our course. This is a very fair check upon our longitude. An excellent method for checking our northing and southing is by observing the sun's meridian altitude, from which we may determine our latitude. This is done with the sextant and mercurial horizon, and should be repeated every alternate day.

Notes of the country are also obtained by taking topographical sketches from some prominent point or mountain peak These are perspective sketches, and are similar to a photograph, but do not possess the same optical accuracy. Bearings are taken to the prominent mountain peaks, and to the heads of water-courses, the smaller streams and mountains being sketched in by eye ; all the distances to these points are estimated and placed above their respective positions in the sketch.

These notes are made in a book 12x6 in., containing two hundred pages, which are divided into inch and a quarter blocks ; these blocks are sub-divided into quarter inch blocks, each of these smaller divisions representing 2-10 of a mile, in the track survey sketches, and two degrees in the topographical sketches.

In the track survey sketches, a small arrow is placed in a corner of each page, showing the meridan, and the courses are drawn accordingly. The time when starting each morning is noted on the left hand side of the page, along with the barometrical reading in feet, directly opposite the station started from. Whenever a halt is made during the day to take notes, the time is first noted opposite the station, the position of which is ascertained in the manner already stated. The notes are then sketched, and as soon as they are completed, at that point, the time of starting is marked beside that of stopping, after which you are ready to proceed. The hills and mountains are denoted by contours, which also show the small streams and gulches in the mountain sides. The trail is shown by a dotted line, and the station by a dot surrounded by a circle. In this method each station is known by the time at which it was made and the geological specimens, gathered at any station, have written upon their labels the time and the date at which they were collected. The geological boundaries are marked with colored crayons, different colors representing different formations.

Camp readings of the mercurial and aneroid barometers are taken in inches every morning and evening, from which we ascertain the heights of our camps, and, since readings, in feet, of the aneroids are frequently taken during the day, we are enabled, after correcting for the weather, to make a complete profile of our track survey. The corrections for the weather may be obtained from some stationery barometer in the vicinity of the survey. In British Columbia we compared our readings with those taken at New Westminister and Spokane Falls.

In plotting the notes obtained in the field, the track survey sheets are first cut out of the note books and pasted together, end to end, with all the arrows pointing in the same direction. This gives you the map as you have plotted it in the field from your pocket compass bearings. You now take tracing paper and trace only the trail from the notes so pasted together, at the same time swing it into the correct position as ascertained from the longer bearings taken with the prismatic compass.

The other notes of the track survey are then traced, relatively to the trail as changed. The bearings and distances of the topographical sketches are then plotted from the point on the track survey at which they were taken, showing the hills and valleys by means of contours. This map is then reduced to a smaller scale by means of the pantograph, and published.

* * *

# PROBLEM IN RAILROAD CURVES.

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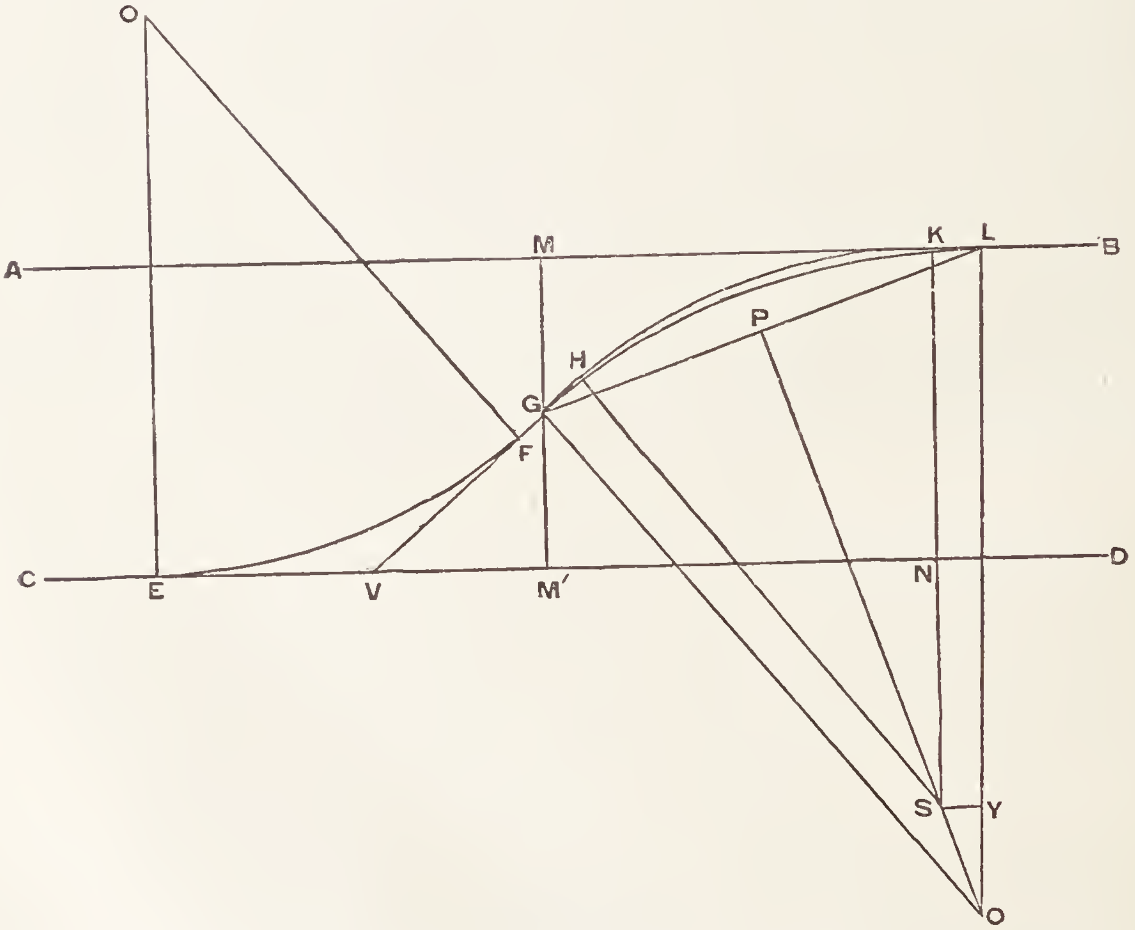
*It is required to connect two parallel tracks by a reverse curve, with a straight line of 500 ft. between the curves at the centre. The distance between the tracks being 2000 ft. = KN, and EN is to be 5000 ft., E and K being the beginning and end of the reverse curve.*

B. A. LUDGATE.



Given.—AB and CD, two parallel tracks, 2000 ft. apart, and the distance from E to N as 5000 ft. (for E and N see below).

It is required to connect these with a reverse curve, each part having the same radius, and having 500 feet of a straight line between the two curves at the centre. In the diagram the curve is to start at E and end at K. From K drop a perpendicular KN on CD; EN is to be 5000 feet.

*1st Solution.*—G is the centre between E and K, GH and GF, each = 250 ft. Make KL = 250. From L drop the perpendicular LO and find the curve whose centre is on LO, and which will pass through the two points L and G. This is got thus:—Join GL, and draw the perpendicular GM, and we have GM = 1000 ft., ML = MK + KL = 2500 + 250 = 2750, and GML is 90°, from which we find G L = 2926.18 ft. and the angle GLM = 19° 59′ nearly, or exactly, 19° 58′ 59.2″.

Bisect GL in P. Then in the △ PLO, we know PL, and ∠s LPO and POL. PL $= \frac{2926.18}{2} = 1463.09$ ft., and ∠ LPO $= 90°$. ∠ LOP $=$ MLG $= 19° 59'$. From which we find LO $= 4281.21$ feet.

Now, a curve of this radius will touch AB in L and FH in G. From G draw FH ⊥ to GO, which will be the direction of the tangent or straight line of 500 ft.

Now, any curve drawn touching AB, as at K, having its centre on the line OSP will also *touch* the other tangent HF in some point as H. And it is the curve that touches AB at K, and HF at H that is required; wherefore, we want the radius KS $=$ HS of such a circle. In the △ SYO we know SY $= 250$ ft. $=$ KL, and SOY $= 19° 59'$, and OYS $= 90°$, from which we find OY $= 687.47$ ft.

Now, SK $=$ OL $-$ OY $=$ YL $= 3593.74$ ft. ∴ the radius of the circles is 3593.74 ft. The other half of the curve is the same as this half.

This radius corresponds to a 1° 35′ 40″ curve, nearly.

*2nd Solution.—*

Produce HF to meet CD in V.
Then EV $=$ VF $=$ T, say.
Now, GM′ $= 1000$ ft.
VM′ $= 2500$ ft. $-$ T.
VG $= 250$ ft. $+$ T.
GM′V $= 90°$. ∴

$$(VG) = \sqrt{(GM')^2 + (VM')^2}.$$

$$(250 + T) = \sqrt{1000^2 + (2500 - T)^2}.$$

From which we find T $= 1306.81$ ft., and
that the ∠ GVM′ $= 39° 58'$.
And ∴ the ∠ EO′F is $= 39° 58'$.
Join O′V. Then in △ EO′V we have
∠ EO′V $= \frac{39.58}{2} = 19.79$.
O′EV $= 90°$,
and side EV $= 1306.81$; from which
we find that O′E, the radius of the
required circle, is 3593.7 ft. as before.
And this radius corresponds nearly to a
*1° 35′ 40″ curve.*

# A RE-SURVEY IN ONTARIO.

## A. E. LOTT.

In this Province re-surveys have been made in only a few cases. The necessity for such a proceeding may result either from the destruction of the posts put down on the original survey, and also of all traces of old lines by means of which they might be re-established, or from failure of the surveyor to do his work properly. In the instance with which the writer is familiar, the original survey was made or reported to have been made in 1821, by P. L. S. Elmore.

At that time lines were only partially run between Concessions V. and VI., VIII. and IX., and IX and X., and besides these no other lines were run, except the boundaries.

About thirty years after the above date, Elmore undertook to complete the survey, but owing to physical incapacity, was unable to either complete the original survey or to properly comply with the law in such cases. The township is about nine and a half miles wide from East to West, and about twelve miles in length, and was divided into eleven concessions running North and South or more nearly about N. 20° W. Ast.

Each concession was divided into 32 lots. These in the original survey were intended to be 30 chs. each, except the last, which was about 22 chs., while the length of the concessions was to be 66⅔ chs , except the eleventh, which was something over 40 chs. When Elmore came back, he gave Concession I., 20 chs., Con. II., 40 chs., Con. III., 60 chs., Con. IV., 210 chs.; V. 70 chs., VI., 60 chs., VII., 49 chs., VIII., 84 chs, IX X and XI., he left much as wood-rangers appointed by lumbermen had blazed them out. He began his chainage at the north and did not continue it to the south boundary, but stopped about lot 10.

Settlers took up lots by the second survey, the real original work never being known by them, except in one or two cases. Lumbermen in fighting in the courts found it necessary to have the lines properly run; and about fifteen years ago a surveyor was appointed to examine and report on the real condition of the township. He first obtained all the information possible from those surveyors who had done work in the township, and then proceeded with his examination.

By his report the only original posts which he could establish were a few of those on the V. and VI. concession line, as far north as No. 28 or 29, and a few of those on the VIII. and IX. line, as far north as No. 16 and 17. The lengths of the first five concessions as recognized by settlers varied from 20 chains to 210 chains, while the other concessions, although by no means correct, were more nearly so than the first five. This report was taken by the government as the basis of the re-survey, and instructions in accordance therewith were given to the surveyor who was appointed to do the work.

The average length of the concessions, excepting the eleventh, was about 70 chains, but according to instructions, the distance between the west boundary and the 5th and 6th Concession line, had to be divided into five equal parts. The distance between the 5th and 6th line, and the 8th and 9th line was to be divided into three equal parts as far north as the last post on the 8th and 9th line. The distance between the 8th and 9th line and the east boundary to the same point north was to be divided into three parts, but as in the original survey, the 11th concession was shorter than the others, the distance between the 8th and 9th line and the east boundary was to be divided in the same proportions as the lengths named in the original survey. That part of the township between the 5th and 6th line and the east boundary, and north of the last original post on the 8th and 9th line, was to be divided into six parts in the same way as the last named part. The concessions had to be divided into 32 lots in the same way. In beginning the work, the southern boundary had to be established, and this was done in the following way: The point where the 5th and 6th line began was found, and a direction for the boundary was assumed, agreeing, as nearly as possible, with some blazes that were found in the swamp in which this point was located, and this line was continued through to the west boundary.

The original corner post between that township and the adjoining one to the west was then found by the aid of some old residents, and the distance from it to the trial line along the course of the west boundary as given by different surveyors. The length of the five concessions and the proper course of the south boundary was then calculated, and the boundary was then run out from the south-west corner, the concessions being laid off at the proper distances.

The west boundary and the 5th and 6th line were then run out, the boundary being established by posts of the adjoining township, and blazes at different places, while the 5th and 6th line was run so that the line between two consecutive original posts was a straight line. The length of the west boundary was taken from the notes of a surveyor who had chained it carefully and the posts were set accordingly. The 5th and 6th line was chained and the distance between each two consecutive posts was divided into the proper number of equal parts explained. Allowance was made for a cross road between lots 5 and 6, 10 and 11, 15 and 16, and so on. The courses of the several concession lines were then calculated so that the concessions should be of equal lengths at any point, and the lines were run. To ensure accuracy tie lines were run across the township every tenth lot, and the points at which the concessions crossed were noted. The lines were continued through to the north boundary, which being the south boundary of a comparatively new township was easily found. If the last lot had more than its proper width the excess was divided back among all the lots, either to the last original post or to the south boundary, each having its proper proportion The south boundary east of the 5th and 6th line was established in the same way as that part west of that line. On the 8th and 9th line the distance was divided, as on the 5th and 6th line. On the 6th and 7th, and the 9th and 10th lines some original posts were sworn to by the settlers and therefore had to be recognized as established posts in the resurvey. Where these posts were found the lines were run in this way: Suppose an original post to be found between 14 and 15 on the 6th and 7th line. The two concession lines, viz., 6th and 7th, and 7th and 8th were run on their proper courses to about the position of the side line between 13 and 14, but no posts were set. An observation was then taken at the original post to ascertain the direction of the side line, which being found was produced both ways to meet the 5th and 6th, and the 8th and 9th lines. The distance between these lines was measured and the point noted at which the side line crossed the concession lines. The distances between those points and the south boundary were then divided among the proper number of lots, and the posts were set up to those between 13 and 14. The course of the 6th and 7th from that point to the original post was calculated and run, and also the course of the 7th and 8th from the same point to a point half way from the original post to the 8th and 9th line.

Then supposing the last original post on the 8th and 9th line to be between numbers 16 and 17, a tie line was run across from the 5th and 6th line to the east boundary along the side line between numbers 17 and 18, and was divided into six parts, giving each concession its proper width and the concession lines were then run from the posts between numbers 16 and 17 through the proper points on the tie-line.

Traverses of clearings, rivers, lakes and roads were made by finding from the field notes the points at which the concession lines cross the several clearings, rivers, etc., and then building on the portions of the concession lines intersected between the two sides of the clearing, lake, road or river a system of triangles or lines from which the shape could afterwards be plotted.

The instruments used in traversing were the transit with stadia, or the micrometer and sextant, or micrometer and compass. Where the transit was used the angles measured were obtained either by finding the angle between each line and the concession line without reference to the real course of the concession line, or knowing the magnetic course of the concession line to find the magnetic course of the several lines by the compass on the transit. The distances were obtained by stadia measurements. The distances and angles or bearings were entered on sketches in the surveyor's field book. Where the micrometer and sextant were used, the angles were measured by finding the angle between each line and the concession line, and the distances were obtained in the ordinary way by the micrometer.

# REFERENCE POINTS

—AND—

# BENCH MARKS.

H. J. KENNEDY.

The object of the present paper is not to be technical in any sense of the term, but merely to call the attention of those who purpose engaging in railway work to a few matters of detail which so far have never been considered sufficiently important to be noticed in any published work known to the writer. At the same time, however, they are of sufficient importance to the young engineer to distinguish him among the older members of the profession as a "clever chap," or a "muddler." The latter reputation, being a very undesirable one, will be retained much longer than the former, and if the present paper succeeds in impressing this fact upon the attention of those who may peruse it, the writer's object will have been attained.

The subject proposed to be discussed is the best practical methods of keeping the original alignment and levels referenced while the work of construction is in progress, so that they may be readily replaced when the work is completed.

When the assistant engineer is alloted his section, his first work is to run check levels over it, placing benchmarks where necessary, and referencing the alignment in some way that it may be picked up at any time during construction if required. The necessity for these reference points must be apparent to all as the work is all cross-sectioned from the centre line, and if it cannot be replaced exactly, the quantities cannot be measured exactly, or the track laid to the proper centres. In a rock side-cutting an uncertainty as to the exact location of the centre line may possibly involve a difference of several hundreds of dollars, or even thousands, although the possible deviation may not be more than a foot. There is, therefore, a temptation to the contractor to dispute the measurements, and claim a remeasurement of his work after its completion if he thinks there is anything to be gained thereby. If he finds the centre has not been well referenced he is certain to think that the cuttings were taken out very wide on the high side.

The usual points to reference are the beginning and ending of each curve (B.C. and E.C.) which are no doubt the best points for convenience, when a suitable reference can be obtained. This, however, is not always the case. There are several methods employed, almost every engineer having some one favorite method to which he adheres in almost every case.

The following are a few of the more common methods :—

I. Having set the instrument over the hub to be referenced, turn off an angle from the line of about 60° to a stump, or some other object at a convenient distance out of the way, and sight to a point marked on the side of it. Now turn the telescope over, and set a hub on the other side of the road out of the way. Again turn to another stump having a point marked on its side, and, having reversed the telescope, set another hub. The point to be referenced will, therefore, be at the intersection of the two lines from the stump to hub respectively; and the distances having been measured to each the reference will be recorded in the book. Of course if there are no stumps convenient stakes may be driven instead; or, indeed, stakes may be driven instead of the hubs, if thought to be more convenient, the principle involved being the same in any case. There is no doubt of this being the most exact method, and the best in many cases, although it has its drawbacks. In the first place the instrument is necessary to re-establish the point; and secondly, there are four points to be kept, and if any one is disturbed the others are useless. Again if the point referenced is to be excavated to more than a few feet, the references are worthless, as they cannot be seen from the point, On the other hand if a high embankment is placed over the hub this method will be found the best that can be devised for replacing it.

II. This method is by measuring the distance to a stump or other permant object on each side of the point and noting distances. This is a readier although somewhat rougher way than the former. Although it is a poor method for either a deep cut or high embankment, it is more convenient and just as reliable as any other, when the hub is about grade elevation. It is preferable to measure the distances to three stumps where convenient, and the station and distance to centre should be marked on each stump.

III. Some prefer to measure the distance at right angles from the line to a permanent point, not only at the hub, but at several stations where convenient. This is a useful method as the stakes may be replaced without the aid of the instrument.

IV. Still another way is to place a hub at the point of intersection of tangents, generally called the PI. This is the best method that can be devised where practicable, but it is not always that it can be adhered to, as where a curve is placed there is always some reason for placing it there, and that reason being generally a hill or a ravine, the P.I. is often inapproachable. In such cases reference hubs are placed at any convenient place on the subtangents of the curve, where they serve just as well as if placed at the P.I.

The sole object of references being to keep the original alignment indisputable and easily found, there should be at least two points referenced in every tangent so that it can be replaced without the trouble of running a curve, besides in re-running a long curve the E.C. is liable to be badly out, the cause, of course, being due to a difference in chainage rather than instrumental inaccuracy. This is a source of annoyance to be met when the chain used on the original location has been stretched a little too long, as is sometimes the case. When, therefore, the B.C. and E.C. can be established independently there can be no difficulty in replacing intermediate stations when required.

The following rules may be laid down for referencing alignment, and if strictly adhered to when laying out work would be a great saving of both time and trouble.

1. Every tangent should have at least two points referenced, and those points should be the E.C. and B.C., if convenient for the purpose.

2. When convenient, a hub should be driven at every P.I. with a high picket behind it; but if not, hubs and pickets may be placed anywhere on the sub-tangents. And if a crosshead or piece of red cloth is placed on the top of each, it can always be seen, and is not likely to be disturbed by the workmen.

3. If the point to be referenced is to be covered by a high embankment, the first method described will suit best; but if in a deep cutting, another point on the tangent will be better suited for referencing.

4. Too many points cannot be referenced, and the transit book should show all information so clearly that a stranger can by it replace any of them.

It is very important that the book should give all information clearly, as it is liable at any time to fall into the hands of some experts whose business may be to search for errors and omissions.

The establishment of bench-marks is a subject needing some forethought, although it does not receive that attention in many cases, which its importance demands.

As previously stated, check levels should be run over the section, and benches established at the same time, where required. To guard against mistakes every bench should be made a turning point, as otherwise a bench might be given the wrong elevation, and cause confusion and loss before the mistake is discovered. A tracing of the location profile should be carried for reference; and a bench placed at each end of every cutting, choosing a stump or other object that will not be disturbed by the workmen; and if near a rock-cutting, a large stump should be chosen, as small ones are liable to be battered down by flying rocks.

It should not be forgotten, however, that every bench should be nearly about the same elevation as the grade, so that the level may be set up on the road-bed to give the workmen the grade elevation occasionally, without changing the instrument.

A bench that has been established either too high or too low for this purpose, will never be used after the work has been cross sectioned, as the first time the grade elevation is given to the workmen, the inconvenience will appear, and another bench will very likely be established in a better situation, so that it is here possible an error may be made if done hurriedly, and without checking back on the original bench. How much better it is, therefore, to place the original bench right at first, where it will be used to estabish the grade at all times.

In recording the benches, great care should be taken to give such information that any one can with the book go directly to every bench and recognise it. Hunting for benches when one is in a hurry, and with incomplete notes, is the most disagreeable part of the engineer's work; and should he dub the one who established the benches a "muddler," the latter has only himself to blame. The writer can well remember a search made for a bench recorded as, "A point on white boulder on south side." But a few hours searching in snow about five feet deep, and an atmosphere forty below zero, revealed the fact that there were white boulders on the south side for miles around that locality, and no way of distinguishing the right one from the others.

A list of benches should be made out, and copied in each level book, giving the station where each is situated, its number, elevation, direction and distance from centre line; and also a full description, so there can be no doubt of its identification by anybody.

There are several reasons for taking this precaution, a few of which may be given for example.

If the snow is deep, how is the bench to be found without knowing the station and distance from centre; or, indeed, if it is a stump, and a bush fire blackens every stump alike, how can it be found, except by the recorded informations.

Again, suppose the number and elevation have been marked on each bench, and recorded, as is commonly done; but if the figures become blackened or burnt off, how can you know one from another, although you may know where to find every one.

These may seem unimportant matters to many who have not been confronted by them, yet they are the points every young engineer who engages in the work is supposed to understand; and cases could be cited where a disregard for them has caused the discharge of the engineer, besides giving his successor a great amount of unnecessary work.

In conclusion it may be well to call attention to the fact that we all make the same mistake in starting out. We get the idea somehow that, by reading the rod to hundredths in cross sectioning work we are getting it down pretty fine, while at the same time we may be neglecting the more important matters; and it is not till we come to calculate the quantities that we see the folly of creating extra work for ourselves for nothing. The rod should be read to the hundredths, of course, in taking foresight or backsight, so the height of instrument will always be correct; but for intermediate readings it is absurd, and goes to show the leveller's greenness.

In cross sectioning work the height of instrument should be checked from bench to bench, and the instrument should never be lifted without checking on a bench, or establishing a point to start from when the work is continued, so that any expert who may be employed to look over the books, may be able to see that every height of instrument can be traced to two bench marks. If this receives sufficient attention, the books must prove the correctness of the work, and no dispute can possibly arise upon that score.

# CROSS-SECTIONING.

W. E. TYE.

In the following paper I will endeavor to illustrate the different methods actually used on the Canadian Pacific Railway in taking cross sections, keeping note books, calculating quantities, etc., both on the prairie and the mountain sections. The first case that I will illustrate is on the Emerson Loop Line, a branch of the C. P. R., running from Emerson to Rosenfeldt.

This road was over almost dead level prairie, and was entirely in embankment. The roadbed was 12 feet wide, and the slopes 1½ to 1. The alignment was good, there being only four curves in the twenty-one miles of line; one of them being the curve to connect with the Pembina branch at Emerson and another to connect with the South Western branch at Rosenfeldt. The work was all "short haul," that is, the material was all obtained within two hundred feet of the place it was to be used. This makes the simplest possible work for the engineer, though far from being the most pleasant, the work being done by grading machines, and almost impossible to make look well. The location having been run some time before, and stakes being set in at every one hundred feet, with number of station marked on each, the first thing to be done, was to run "Check Levels," to see if the location levels were correct.

The level books were all ruled in the following form :—

| Station. | Back Sight. | Intermediate. | Fore Sight. | Height of Instrument. | Elevation. | Remarks. |
|---|---|---|---|---|---|---|
| | | | | | | |

And all records of levels were kept in this manner.

Bench marks were put in not more than half a mile apart; this being close enough for this kind of work. B.C.'s (beginning of curves), E.C.'s, and all centre line hubs were referenced in the following manner :—

Two hubs were driven, one on each side of the line at right angles to it, and exactly fifty feet from it.

Thus after the centre had been built over, by setting the transit over one point, sighting to the other and measuring fifty feet, would give you the centre again.

This method is simple and quick, but *not* accurate enough when curves are numerous or sharp. Besides the beginning and end of every curve, we referenced the centre line hubs, that is the points at which the transit had been set up on location.

Our party consisted of an engineer, a rodman, an axeman, and a cook.

Cross section books were kept in the following way:—

| Sta. | Eleva. | Grade. | Rate of Grade. | Left Slope | Cent. | Right Slope | Area. | Mean Height | Dis. | C. Yds. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 324 | 1270.8 | 1274.00 | LEVEL. | L | -3.2 | L | | | | | |
| 325 | 1269.4 | 1274.00 | | L | -4.6 | L | | | | | |
| 326 | 1270.4 | 1274.00 | | L | -3.6 | L | | | | | |
| 327 | 1271.2 | 1274.00 | | L | -2.8 | L | | | | | |

The elevations, or height of ground, were first transferred from level book to second column of cross section book.

The elevation of grade was calculated for every 100 feet. The rate of grade and points at which the grade changed being found from profile, and entered in third column. The rate of rise and fall per 100 feet being placed in fourth column. Then subtracting the ground elevation from the height of grade, or vice versa, gives the fill or cut at the centre. For instance, the ground elevation at station 325 is 1269.4. This subtracted from 1274.00, the height of grade, gives a difference of 4.6, and the grade being higher than the gradards shews that it is a fill, and is written —4.6.

The ground in this road was practically level. In no cross section was the fill at the slope stakes found to differ from the fill at the centre by more than two-tenths. This, of course, simplified the work of taking the cross sections, very much. A table was made shewing the distance of the slope stake from the centre for each tenth of fill.

For instance, if the fill be 4.0 ft., then the slopes being 1½ to 1, and the half width of the road bed being six feet, the whole distance of the slope stake from the centre would be twelve feet. In the same way the table was made up to ten feet, this being all that was required on this road. A sample of the table up to two feet is here given.

| Fill. | Dist. out of Slope Stake | Fill. | Dist. out of Slope Stake |
|---|---|---|---|
| .0 | 6.0 | 1.1 | 7.7 |
| .1 | 6.2 | .2 | 7.8 |
| .2 | 6.3 | .3 | 8.0 |
| .3 | 6.5 | .4 | 8.1 |
| .4 | 6.6 | .5 | 8.3 |
| .5 | 6.8 | .6 | 8.4 |
| .6 | 6.9 | .7 | 8.6 |
| .7 | 7.1 | .8 | 8.7 |
| .8 | 7.2 | .9 | 8.9 |
| .9 | 7.4 | 2.0 | 9.0 |
| 1.0 | 7.5 | | |

The only implements used in taking cross sections here were one fifty-foot tape, one axe, and piece of red chalk for marking the stakes. The stakes for marking the slopes, had already been distributed; two being left at each station.

The duty of the rodman, was to mark on the centre stake the fill which the engineer gave him from the note book. The engineer and the axeman then measured out the distance found in the above table opposite this required fill. By using this table, no calculations were required to be made in the field.

In this description of ground, a good party could cross section a mile of line in very little over an hour.

When the ground was not level across, but only required a reading at the centre and at each slope stake, the cross sections were either taken with the level or a small hand level.

The instruments generally used were a hand level, a rod, a tape and an axe, a small sharp pointed stick about four or five feet long was carried to rest the hand level on when in use.

To cross section this, you would drive your stick into the ground, somewhere near the station. The rodman would hold at the centre of grade; sight through your level to the rod and note the reading. If it is a fill, substract the reading. Say the rod in this case read 3.2; this substracted from 6.0 gives a fill at the hand level of 2.8.

You see that the ground falls to the left about two feet, which would make a fill there of eight feet, which would require to be nineteen feet out, (the road bed being 14 feet and slopes 1½ to 1). The rodman and axeman measure out nineteen feet and give you a rod reading there—say the rod read 5.4, this added to 2.8 gives you a fill of 8.2. So you see you are not far enough out, so try 19.6. The rod reading here is 5.6, and the fill 8.4, which is the correct place. Sometimes three or four trials are necessary; but a good rodman will usually come very near it the second time. A stake is marked, the number of the station on the one side, and the distance out, in this case 19.6, on the other, and driven firmly into the ground.

Had station 716 been a cut, the rod reading 3.2 would have had to be added to the cut at the centre, to find the height of the hand level above the grade, and the reading at the slope stake subtracted to find the cut there.

At the beginning and end of every cut, three small grade hubs, or stakes about half a foot long and two inches in diameter, are driven so that their tops are exactly at grade, one at the centre, and one each at grade ten feet right and left of the centre. These are always put in with the level. Cuts are taken out with a twenty foot base; a road bed of fourteen feet and a ditch on each side three feet wide.

Where cuts are numerous it is best to put in a bench mark near the mouth of each.

On heavy mountain work, the party usually consisted of an assistant engineer, a rodman, chainman and axeman.

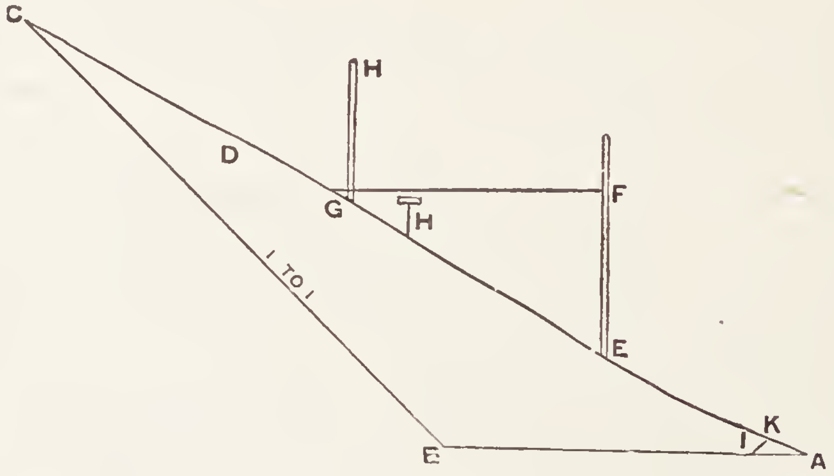
Each party was supplied with a transit, level, telescope rod, fifty foot chain and pickets. Hand level, one cedar rod, from 20 to 24 feet long, two of 15 feet each, and one light rod six feet long, two or three tapes fifty and one hundred feet long, and divided to tenths, and about two hundred feet of battery wire was found to be very convenient.

The rods were made of cedar, for lightness, and were each provided with small level-bubbles.

On the long twenty foot rod, and one of the fifteen foot rods, these were placed so as to shew when the rod was perpendicular, and on the other so as to shew when horizontal.

The locating party put stakes in at every fifty feet, and as the ground was very rough, the curves very sharp, 8°, 9° and 10° curves being numerous, and tangents very short, often not more than 200 feet long; all the plusses, or intermediate points, where cross sections were required, were put in with the transit.

On long earth slopes, where the slope of the ground was regular, and not many readings required between the centre and the slope stake, the best way to cross section was with the hand level and long rod.

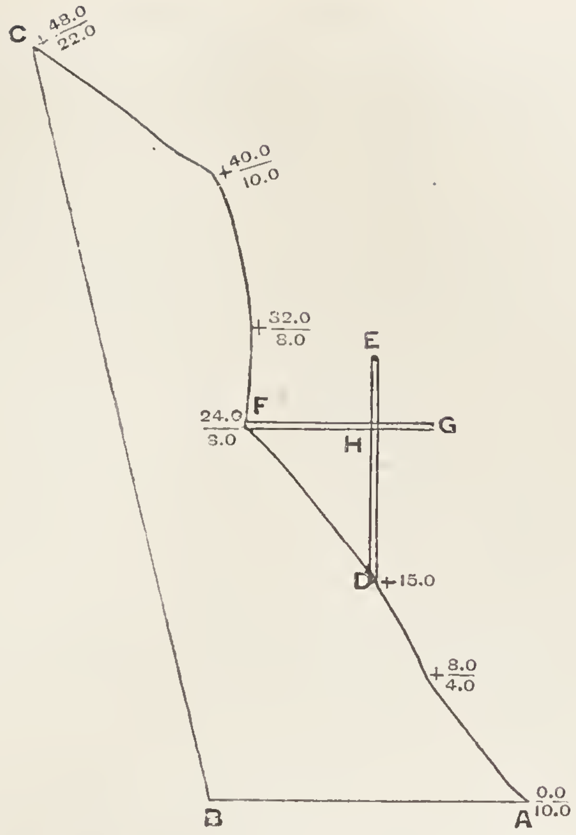


The rodman holds the long twenty-four foot rod perpendicular at the centre E, the cut at which is known from the cross section book. One end of the tape GF is fixed to the upper end of the rod by a hook or staple. The chainman takes the other end and goes up hill to G until he is about level with the top of the rod.

The engineer takes a pointed stick and drives it firmly into the ground at H on which he rests his hand level and sights to the rod EF, this reading added to the cut at E gives him the height of his level above the grade AB. The reading on the rod GH substracted from this height gives him the cut at G. The rod EF; is then moved to G and the process repeated up hill until a point C is found, at which the distance from the centre is just ten feet more than the cut, (the slope being 1 to 1 and the base twenty feet).

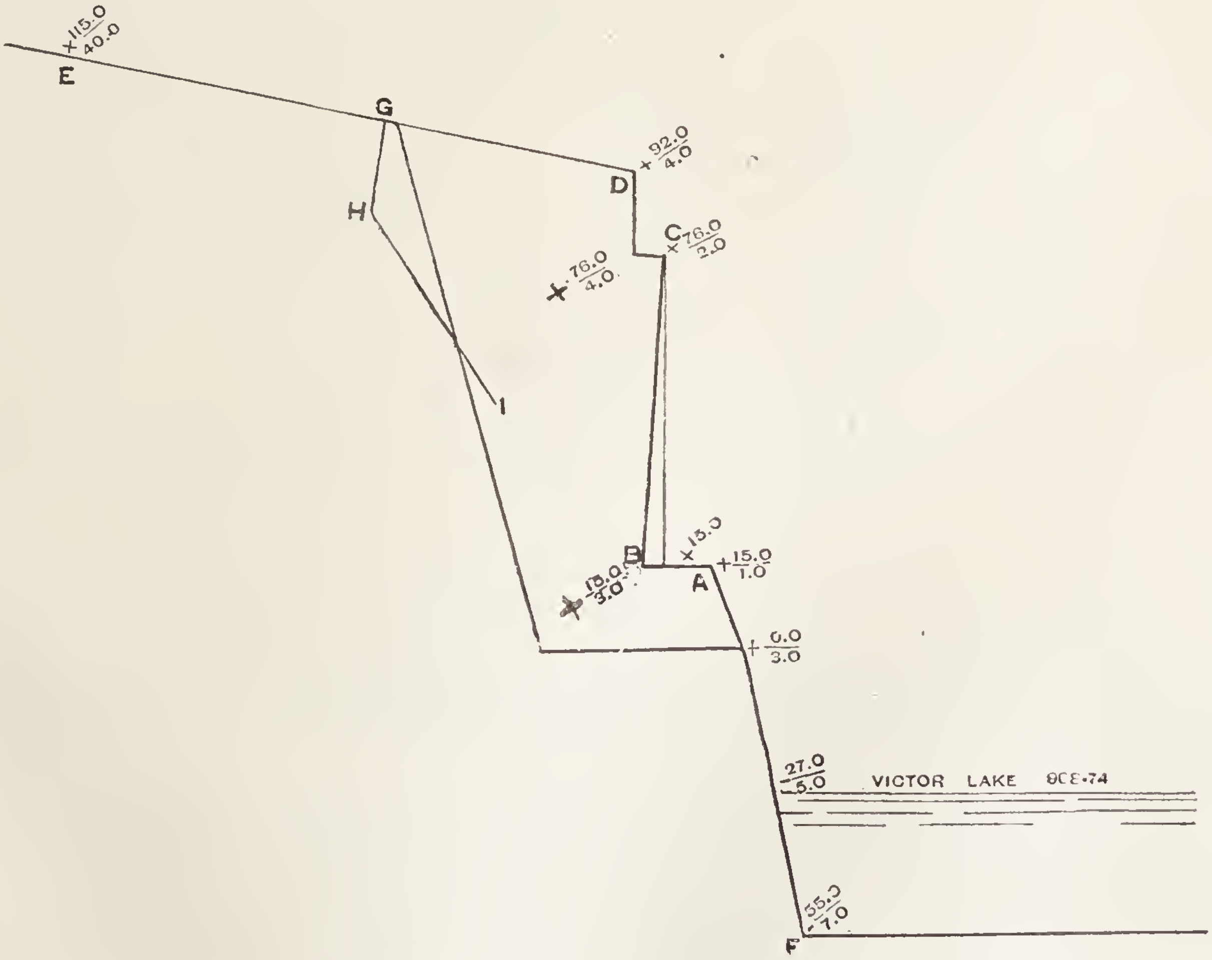
The different rod readings are kept on a small slip of paper, the necessary ones only being entered in the cross section book, these readings are necessary at the centre and at each slope stake, and also at each change in the slope of the ground as at D, or in general, so that the slope of the ground may be uniform between each reading.

On ground where the slope soon runs out to grade, the whole piece is taken out instead of leaving the small triangle AIK, K being the place where the lower slope stake would come with a 1 to 1 slope. On very irregular rocky grounds when changes of slope are numerous, as in the accompanying figure ABC, the fifteen foot rods are used. One rod DE is held perpendicular at the centre, while the other is held horizontal at F, the levels with which the rods are provided shew when they are perpendicular



and horizontal, and their intersection shew on the vertical one the height of F above D, and on the horizontal one the distance out from the centre. H D added to the cut at D gives the cut at F.

There are many cases in which the rods are not long enough to reach from one accessible point to another; some other device must then be adopted. The following is an example:

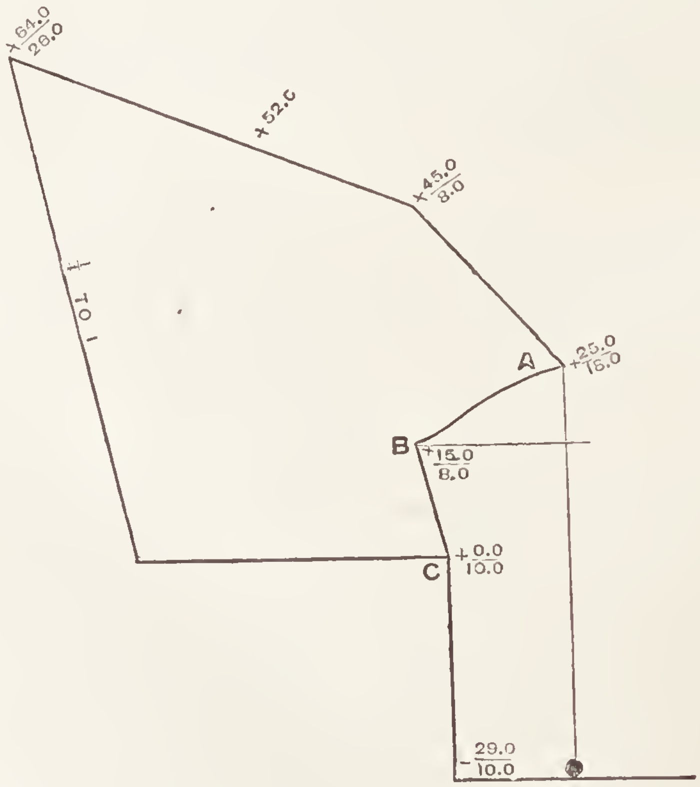


The centre A was accessible; and by going back on the line it was possible to climb up and get at D; the great difficulty here was to get the cut at C. A long rope was tied to a tree at E, and by this we could climb down and get to C.

A tape line with a heavy leaden plummet was first hung over the face of the cliff; but this was found to present too much surface to the wind, and was impossible to keep steady. We then got a quantity of battery wire made of the best copper wire, wound round with oiled cotton, and attached the plummet to it, which was marked at every five feet by pieces of flannel tied to it. It was then allowed to hang over the cliff, and lowered till the lower end was exactly level with the centre, and the height measured on the wire, this added to the fifteen feet cut at the centre gave the cut at C. The distance out was found by measuring from the centre to the plumb line. The height of D above C was found in the same manner. The water level of Victor Lake and the height of grade being known, the fill at the water's edge was easily determined. Soundings being then taken at F, etc., and the depth of the water added to the fill at the water's edge gave the total fill at F, etc.

This rock was badly broken at GHI, so that it was impossible that a ¼ slope would stand. We measured back to E and put in a stake to measure from and find the slope it actually did take.

The diagram below shews another place near Victor Lake. The cross sections as far as A were taken in the usual way, it being necessary in this case, as in a great many more, to have ropes to hold on by. A 100 foot tape was hung over the cliff in such a way that the fifty foot mark just touched A, the last point measured to.



The trouble was now to get to B, but by a combination of ropes this was managed. The horizontal rod was then held out from B, and the intersection read.

The cut and distance out to A could then be easily determined. When the rock was covered with earth to any extent, the earth had to be stripped off the rock, and the rock re-cross sectioned. When there was not more than a foot or two of earth, the depth of earth was often found by driving an iron bar through it till rock was found. Great care had to be taken in using this method, and it could only be used when the earth above the rock was entirely free from boulders. When the rock was covered with earth it was taken out in the following manner:

The rock was taken out to a slope of $\frac{1}{4}$ to 1, a berme of three feet being left on top of the rock, and the earth taken down to a slope of 1 to 1.

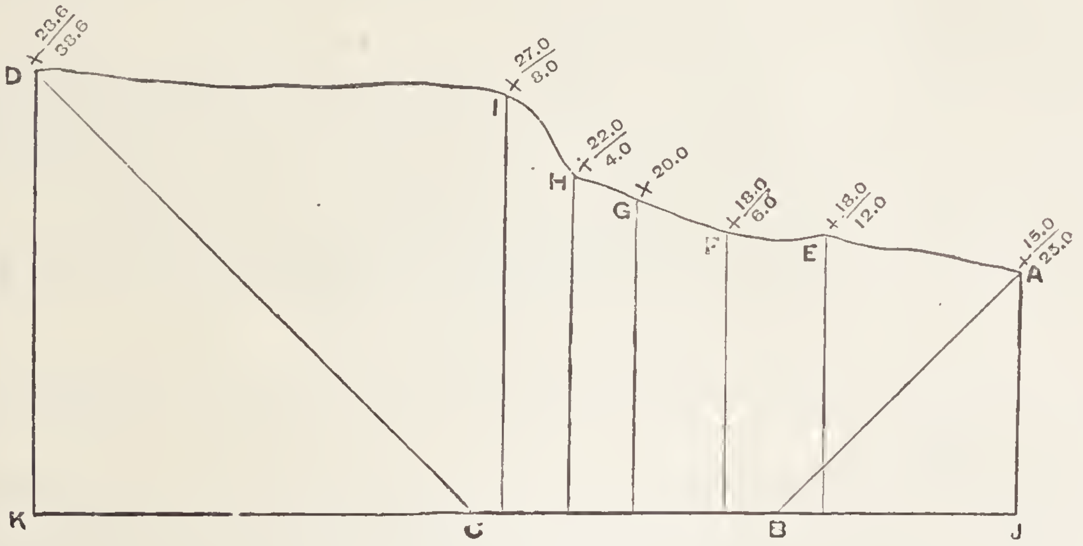
Cross section books were kept on the following manner :

| Station | Elevat'n | Grade. | Rate | Left. | Centre. | Right. |
|---|---|---|---|---|---|---|
| 729 | 1992.00 | 1940.0 | $\frac{1}{.0}$ | $\frac{+64.0}{26.0}$ | +52.0 | $\frac{+45.0}{80}$ $\frac{+25.0}{18.0}$ $\frac{+15.0}{8.0}$ $\frac{00}{100}$ $\frac{-29.0}{10.0}$ |

A separate book was kept for quantities, and all cross sections were plotted to scale, on paper specially made for that purpose. Great care has to be taken on this kind of work to get your B.C.'s and E.C.'s correctly referenced.

One end of each reference line should always be on a tree when possible as it is more easily found, when well blazed. The distances should also be measured to aid in finding the hubs.

The first thing to be done after the sections have been plotted is to calculate the areas.



Let ABCD be the sections to be calculated.

Some engineers first reduce this graphically to an equivalent triangle, and then calculate the triangle ; others, again, divide it into a number of triangles scale the sides and calculate ; but the best way, in my estimation, is to divide it into a number of trapeziums by dropping perpendiculars from AEFG, and all points at which the slope changes, on the base BC or BC produced. The different dimensions of these trapeziums being known, they can be calculated and added together, give the area of the figure AJKD, which is too large by the triangles, AJB and DKC. These can be calculated and subtracted and you have the required figure ABCD.

The calculation of the end areas should always be checked over before anything further is done, as the accuracy of all the following work depends on it.

To calculate the cubical contents, two methods were used by different engineers. The first by " average end areas." By this method the quantity book was kept in the following method :

| EXCAVATION. | | | | | | EMBANKMENT. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Area. | M. Area | Dis. | C. Yds. | C. Yds. per Sta. | Station | Area. | M. Area | Dis. | C. Yds. | C. Yds. per Sta. |
| 618 | 2042.0 | | | | | | | | | | |
| +25 | 1896.6 | 1969.8 | 15 | | | | | | | | |

To calculate the quantities by this method, you add the two end sections and divide by two, multiply this quantity by the distance or length and divide by 27. The result will be the number of cubic yards.

A table on the back of Trautwine's excavation tables gives you the number of cubic yards corresponding to every one-tenth of a foot of area, for 100 feet lengths.

To use this, you turn up the tables till you come to the required area ; opposite this you will find the required number of cubic yards, if the mass is 100 feet long. If not, multiply by the length and divide by 100.

This gives results too large by a quantity represented by the formula $\frac{s\,l\,d^2}{6}$, where $s$ is the rate of the slope to unity, $l$ the length, and $d$ the difference in height between the end sections.

Another method is to deduce a mean area of the prismoid from the middle height, or arithmetical mean of the extreme heights, and multiply by the lengths. This method gives results too small by $\frac{s\,l\,d^2}{12}$. (For demonstration see Gillespie's Roads and Railroads, appendix A, page 354).

For instance, if the difference in the extreme heights be 10 ft., the slope 1 to 7, and the length 25 ft., then $\frac{s\,l\,d^2}{12} = \frac{1 \times 25 \times 10^2}{12} = 208.3$ cub. ft. = 7.7 cub. yds.

One of the best books for railroad calculations is Rice's Excavation and Embankment Tables.

This contains, first, a table of areas of level, cross sections for every foot and tenth of a foot in height for the various widths of roadbeds, and rates of slopes. Second, tables of level cuttings for every tenth of a foot for prismoids 100 feet long, and also the correction to be added by the formula $\frac{s\,l\,d^2}{12}$.

When using this method, the quantity book was kept in the following form :

| EXCAVATION. | | | | | | EMBANKMENT. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Area. | M. Hgt. | Dis. | C. Yds. | C. Yds. per Sta. | Station | Area. | M. Hgt. | Dis. | C. Yds. | C. Yds. per Sta |
| | | | | | | | | | | | |

The areas of the cross sections were entered on the second column. From the first part of Rice's tables the height of an equivalent level sections was found and entered in the third column, the distance between the sections being entered in the fourth column.

To find the number of cubic yards in a prismoid, you add the two mean heights together and divide by 2. Find the number of cubic yards opposite this number in second part of tables, and to it add the number of cubic yards in correction table opposite the difference between the two mean heights, (column three.) Multiply by the length of the prismoid, (column four,) and divide by 100. The result being the number of cubic yards in the mass by the prismoidal formula.

When the ground is level across, it is not necessary to calculate the areas, the centre height being entered direct in the mean height columns.

When there are only three readings in the cross section, one at the centre and one at each slope stake, the area is calculated by Trautwine's rule. The extreme horizontal width multiplied by half the centre depth, plus the sum of the side heights multiplied by a quarter of the road bed.

* * *

# ASPHALT PAVEMENTS.

E. F. BALL.

Before entering into the details of laying asphalt pavements, perhaps it would be advisable to refer briefly to the main features of their construction for the benefit of those who have not yet had occasion to study them.

Asphalt pavements were first constructed in France, in 1854, from a rock called asphalt rock, composed principally of carbonate of lime, saturated with a bituminous substance, somewhat resembling tar. Upon heating this rock it falls to a partially coherent powder, which when spread upon the foundation prepared for it, rammed, rolled, or otherwise compacted, assumes all the hardness and toughness of the original rock. It was found, however, that by mixing a suitable powder, as sand, carbonate of lime, etc., with a suitable cementing substance, such as asphalt obtained from the island of Trinidad, that a pavement could be made similar to that from the asphalt rock, possessing all its advantages, and when sand was used, having the additional one of not becoming slippery in wet weather.

A great diversity of opinion existed in regard to asphalt pavements, some upholding and others condemning them. The principal reason of their failure at first was owing to the fact that entirely unsuitable materials were used to take the place of the carbonate of lime and the asphaltic cement in the natural asphalt rock, as will appear from Mr. D. K. Clark's and Mr. Gillmore's works.

One of the principal points in the preparation of the matrix, or asphaltic cement, is to get it of the right consistency. For this purpose heavy petroleum oils are added to the refined Trinidad asphaltum in such proportions as will enable the mixture to maintain a proper degree of hardness, both summer and winter. Too much oil causing it to become soft and sticky in warm weather, and too little rendering it brittle and liable to crack in cold weather

In many cities in the States, especially in Washington and Buffalo, asphalt pavements have been laid very extensively and successfully. The method used in Buffalo at the present is practically the same as described by Gillmore.

Following are extracts from the "Inspector's copy of the specifications and description for grading, curbing, and paving of Linwood Ave., Buffalo, N.Y."

"Upon the sub-grade prepared as above mentioned, and between the curbstones firmly set as described, shall be laid a bed of Hydraulic Cement Concrete, six inches in thickness when compressed, to be made of one part best quality, freshly burned Rosendale, Buffalo, or Portland Cement, and two parts of clean sharp sand, free from clay, mixed dry, and then made into a mortar with the least possible amount of water. Broken stone not over two and one-half inches in their largest dimensions, thoroughly cleansed from dust and dirt, and drenched with water, must then be incorporated immediately with the mortar in such quantities as will give a surplus of mortar when rammed. This proportion when ascertained will be regulated by measure. Each batch of concrete must be thoroughly mixed, the mixing being continued on the board until each piece of stone is completely coated with mortar. It must then be spread, and at once thoroughly compacted by ramming until free mortar appears upon the surface. The whole operation of mixing and laying each batch will be performed as expeditiously as possible by a sufficient number of skilled men.

"No gravel must be used in the concrete," only pieces obtained by fracture.

"The upper surface must be made to conform to the contour of the roadway or pavement, and when finished must be protected from the action of the sun and wind until set" This is accomplished by spreading a little earth over it.

### "WEARING SURFACE OR PAVEMENT PROPER.

"Upon the base above described the wearing surface is to be laid, two and one-half inches in thickness when compressed, and composed of,—

"1st. First Quality Refined Trinidad Asphaltum.

"2nd. Heavy Petroleum Oil, or the residuum of the same.

"3rd. Fine sand containing not more than one per centum of Hydrosilicate of Alumina.

"4th. Fine powdered Carbonate of Lime.

"The Trinidad asphaltum (so called) must be specially refined and brought to a uniform standard of purity and gravity. The heavy petroleum oils which may be residuum by distillation of the petroleum oils as found in the market, must be free from all impurities, and brought to a specific gravity of from 18° to 20° Beaumé, and a fire test of 250° Fahrenheit.

"By melting and mixing these two hydrocarbons, (petroleum oil and asphaltum), the matrix of the pavement, called asphaltic cement, is manufactured, which cement shall have a fire test of 250° Fahrenheit, and at a temperature of 60° Fahrenheit, shall have a specific gravity of 1.19. They must be mixed in about the following proportions by weight.

| | |
|---|---|
| "Pure Asphalt - - - - | 100 parts. |
| "Heavy Petroleum Oil - - | 20 " |

"The asphaltic cement being made in the manner above described, the pavement mixture will be formed of the following materials and in the proportion stated.

| | | | |
|---|---|---|---|
| "Asphaltic Cement from - - - - | 12 | to | 16 |
| "Sand " - - - - - | 73 | " | 67 |
| "Pulverized Carbonate of Lime - - | 15 | " | 17 |
| | 100 | | 100 |

"The carbonate of lime may be reduced or omitted entirely when suitable sand can be had. In order to make the pavement homogeneous the proportion of the asphaltic cement must be varied according to the quality and character of the sand.

"The sand and asphaltic cement are to be heated separately to about 300° Fahrenheit. The pulverized carbonate of lime while cold is mixed with the hot sand in the required proportions, and is then mixed with the asphaltic cement at the required temperature and in the proper proportion, in a suitable apparatus, which will effect a perfect mixture.

"The pavement mixture prepared in the manner thus indicated, will be laid on the foundation in two coats. The first coat, called the cushion coat, will contain from two to four per cent. more asphaltic cement than given above; it must be laid to such a depth as will give a thickness of one-half of an inch after being consolidated by a roller.

"The second coat, called the surface coat, prepared as above specified, must be laid on the cushion coat, being brought to the ground in carts at a temperature of about 250° Fahrenheit; and if the temperature of the air is less than 50°, iron carts with heating apparatus must be used in order to maintain the proper temperature of the mixture. It must be carefully spread by means of iron rakes, in such a manner as to give a uniform and regular grade, and to such depth, that after having received its ultimate compression of two-fifths, it will have a thickness of two inches. The surface must then be compressed by hand rollers, after which a small amount of hydraulic cement will be swept over it, and it must then be thoroughly compressed by a steam roller weighing not less than two hundred and fifty pounds to the inch run; the rolling being continued for not less than five hours for every thousand yards of surface.

"The powdered carbonate of lime will be of such degree of fineness that 16 per centum, by weight, of the entire mixture for the pavement shall be an impalpable powder of limestone, and the whole of it shall pass a No. 26 screen. The sand must be of such size grain that none of it will pass a No. 80 screen, and the whole of it shall pass a No. 20 screen.

"In order to make the gutters, which are consolidated but little by traffic, entirely impervious to water, a width of from twelve to eighteen inches next the curb must be coated with hot pure asphalt, and smoothed with hot smoothing irons, in order to saturate the pavement to a certain depth with an excess of asphalt."

## DESCRIPTION OF IMPLEMENTS.

The hand roller referred to above, consists of a hollow iron cylinder about three feet in diameter, and three or four feet long, attached to a handle about twenty feet long. It is operated by two men wearing shoes without heels, to avoid making deep indents in the hot asphalt.

The steam roller consists of a boiler and engines mounted on three iron cylinders. The one forming the driving wheel, and bearing the greater part of the weight of the engine, is about four feet in diameter and four feet long. The hind roller is divided into two parts, placed side by side, and arranged to turn about an upright axis like the front wheels of a carriage, so that the whole machine may be steered in any direction. The engines consist of two cylinders with reversing gear, acting upon the driving roller by means of a beveled gear.

The sheet asphalt pavement, thus constructed, is impervious to water, smooth, noiseless, except for the clicking of the horses' hoofs, easily cleaned, not slippery, very durable, and capable of withstanding heavy loads. An instance is mentioned of a truck weighing four tons, carrying a boiler weighing twenty-one tons, passing over a sheet asphalt pavement without leaving a track. From the fact that it is entirely impervious to water and noxious liquids, promptly discharging them into the side gutters, it will be seen that it is a most healthy pavement; while its smoothness and noiselessness make it desirable for pleasure drives and for streets lined with residences. The effect of travel upon asphalt is to compact rather to wear it away, and if the foundation should settle, the sheet of asphalt will conform to it.

No. 2. 1887-8.

# PAPERS

READ BEFORE THE

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OF THE

# School of Practical Science,

# TORONTO.

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# PREFACE.

THE Engineering Society of the School of Practical Science was founded in the spring of 1885, through the exertions of a few of the students in the Department of Engineering; Messrs. Herbert Bowman of the third year, and T. Kennard Thomson of the second year, being the principal promoters Meetings are held every second and fourth Tuesday of each month during the session, at which papers are read and engineering questions discussed. In order to keep alive the interest of graduates in the success of the Society, some of the leading papers, contributed during the previous session, will be published annually. The majority of the writers are students, the greater part of whose time is necessarily spent in acquiring information already in possession of the profession, and who can ill afford to spend much of it in attempting original work. While this is true, it was yet felt by the publication committee that it would be useless to publish papers the information in which had been gathered chiefly by reading. No paper, therefore, has been printed in the present selection, the writer of which has not had some experience in the subject dealt with.

It is hoped by the general committee of the Society, that graduates of the School and former students, who are now engaged in active work, will make endeavors to contribute papers relating to their work to be read at meetings of the Society.

The present edition consists of one thousand copies, which will be widely distributed among Engineers and Surveyors.

# RODDING ON RAILROAD WORK.

## I. RODDING ON SURVEY.

*Mr. President and Gentlemen :—*

In treating this subject I have divided it into what seem to be its two natural divisions, viz : Rodding on Survey and Location, and Rodding on Construction : and we will first consider Rodding on Survey and Location.

Before going into that, however, it may not be out of place to give a general description of the way in which railroad work is done.

We will suppose, then, that some company has decided to build a line from some one point to another. First, some of the company's engineers go over all possible routes, noting levels with an Aneroid Barometer, or some such instrument, and marking the lines over which they are travelling on maps of the localities. After making several such surveys, the engineer in charge compares notes of all the lines, and then decides upon the approximate locality of the line.

It is at this stage that the survey party goes out, and they first make what are called trial line surveys. In these surveys the line is run by transit, and the levels are taken with the instrument.

The object of trial lines is merely to get definite information regarding the various routes that may be taken, and so it is necessary to measure all horizontal angles, in order that the plan of the line may be plotted. The levels, showing the nature of the ground on each line, are also plotted, and such a drawing is called a profile.

Several trial lines are run, and then the information gained is compared, and one is selected as the line to be built. This line is then "located," that is, the line on which the centre of the track is to be laid is staked out on the ground, all tangents, curves, etc., being laid out exactly as they are to be in the finished line, the methods used being similar to those used on survey.

After the line has been located, plans and specifications are drawn up and the contracts let.

While this is being done in the office, the work has also been divided, first, in "divisions," as they are called, and each division put in charge of an engineer, who is called the "Divisional Engineer," and who has to oversee the general management of the work on his division. Each division is subdivided into "sections," and the sections are given in charge of a "Sectional Engineer," or, as he is more commonly called, an "Assistant Engineer."

Each assistant engineer is given a rodman and an axeman, and this party of three then go out on their section and proceed to lay out the work for the contractor.

For the benefit of those unfamiliar with the subject, it may be well to describe the method of running a line by transit.

At the point from which the line is to be started, a "hub" is driven and a tack put in it, the tack denoting the exact point. The instrument is then set up over this tack, and the bearing of the line to be run being known, it is set off by means of the compass on the instrument, and another hub is set as far away as the transitman can conveniently see. The instrument is then set up over this second hub and sighted on the first; the telescope is turned over and a third hub set, and so on to the end of the line. A "hub" is a piece of wood about 8″ long, 4″ or 5″ broad, and from 2 to 4 inches thick; pointed at one end and flat at the other. The method of setting a hub is as follows: The transitman sights on the back picket, turns the telescope over, and a picketman who has gone ahead and lined himself in as closely as possible, holds his picket plumb, and the transitman motions him to one side or the other until he is on line. He then makes a mark with his picket, and the axeman drives the hub until its top is about half an inch above the ground. The picketman holds his picket up again on the hub, and the transitman lines him in exactly. He then makes a mark in the hub with the shoe of the picket, and drives a tack in that mark. This tack will be seen to be exactly on line.

The chainmen then come along and set in stakes every hundred feet, that is every chain, for a 100′ chain is always used. They line themselves in by the instrument and the back picket, and as they go along number each stake, numbering the first "0" and the end of the first chain "1," and so on; so that, for instance, a stake numbered "23" would mean 2,300 feet from the starting point.

These stakes are called "stations" or "centre stakes." After the chainmen come the levellers, and this introduces us for the first time to the rodman on survey. The general method of running levels is as follows: The levels are started from some definite point, for which an elevation is assumed. The instrument is then set up and levelled, and by means of a sight at the rod held upon the starting point, an elevation is found for the instrument, corresponding to that assumed for the starting point.

Readings of the rod are then taken at every centre stake, and the elevations determined by subtracting the reading at each station from the elevation or height of the instrument.

When the rod gets too high or too low for the instrument, or cannot be distinctly seen by it, the elevation of a point is found, and the instrument is then moved and set up again, and the height of the instrument again determined from that point, by knowing the elevation and taking the reading of the rod held on it, thus finding how much higher the instrument is than the point. This process is repeated over and over again until the end of the line is reached. The elevations found in this way are of course comparative, and when plotted form a profile, which, of course, shows the comparative heights of points 100′ apart on the line, and thus gives a general idea of the surface of the ground.

It might appear from the above that the rodman's duties on survey are rather light and simple, and so they really are; but this is only an additional reason why they should be well performed; and this brings us to our subject proper—Rodding on Survey and Location.

The first, and perhaps most important, duty of a rodman is to hold his rod plumb. This is absolutely necessary in order that the levels may be correct, and although it would appear a very simple matter, it really requires a good deal of attention.

First, then, get a firm footing for yourself behind the rod, and then hold it lightly between the fingers and balance it until it feels plumb both sideways and forward and backward. Then call out the number marked on the stake. This calling of the numbers must never be forgotten, as the leveller always depends on it to find out whether any number has been repeated or omitted by the chainmen in marking the stakes, and thus to check the chainage, for an omission or a repetition would shorten or lengthen the line, respectively. If an error is noticed, be sure the leveller notices it also, when you call out the number of the station.

Besides giving a sight at every station, it is also necessary to give sights at all points where the surface of the ground changes abruptly. Such a sight is called a "plus," and derives its name from the fact that the rodman must find and call out the chainage of that point. The distance of the point from the last station may be either estimated by the eye, or what is better, paced off. In calling out a plus, call out the full station as well as the plus; thus "365 + 33."

In order to recover the levels at any future time, it is necessary to find the elevations of definite points all along the line, and note their positions and elevations, so that they can be found without difficulty, and the levels started from them if necessary.

These points are put in about every ten or fifteen chains, and are called "bench marks;" and as naturally hard, definite points are rare, bench marks must usually be made.

The most common method is to cut the bench mark on the root of a tree near the line, and this requires not a little skill and practice if the bench is to be a good one.

First, then, choose a tree which can be distinctly seen by the instrument, and which has a root projecting from the trunk on the side next to the line. Then with the hatchet, which the rodman always carries, make a vertical cut down on the root, then an inclined cut, so as to take out a "V" shaped piece of wood. Then cut away the sides of the piece thus left, so as to form a pyramid. The top of this pyramid is then cut off horizontally, so as to leave a square about half an inch in diameter. This is the bench mark, and to prevent any possible mistake it is a good plan to mark the point with a little chalk cross on top.

When the bench mark is put in, the elevation is always marked on something near it, and in case the bench is on the root of a tree, the elevation is marked on the same tree. To do this, the face of the tree must be blazed; that is, the bark cut off and the wood smoothed so that it can be written on. In blazing the tree be sure not to leave the bark in shreds or partly cut away at the sides, for it will grow over the cut very quickly if left in that way; and also cut well into the wood of the tree, or otherwise the blaze will become black and the figures on it cannot be seen.

On the blaze is then marked with red chalk the letters "B.M.," (bench mark), and the elevation thus:— $\frac{\text{B.M.,}}{\text{886.74.}}$

Sometimes also the levellers number their bench marks, and if so, it should be marked thus:— $\frac{\text{B.M. No. 23,}}{\text{886.74,}}$ and not the following:—(B.M., No. 23, 886.74), for with the latter way a new rodman and leveller might in some way mix up the number of the bench and its elevation.

In marking a bench do not make the figures very large, but make them very distinctly and neatly, for nothing looks better in going along the line than to see well-cut, neatly-marked benches; the centre stakes all standing plumb and also neatly marked; and in fact this applies to every stake that has to be driven and every number that has to be marked—drive the stakes plumb and mark the numbers neatly.

But of course it is not necessary to cut a bench mark on a tree; any hard, definite point which is certain not to be moved will answer very well; for instance, the top of a boulder or a stump, or a long stake driven solidly into the ground; but in these cases especially it is necessary to mark the point used by a cross, or some such mark, so that there can be no possible mistake in finding the point again. In order that bench marks may be found at any future time without any delay, it is necessary that the rodman should be able to "locate" himself, that is, to recognize any part of the line on which he may be put, and then to remember approximately where the nearest B.M. is. Of course this is pretty difficult, but if a mental note is made of the neighborhood of every B.M. as i is cut, with a little practice one is able to locate oneself almost exactly and with comparative ease.

When the leveller can no longer see the rod distinctly enough, he finds the elevation of some point and moves the instrument as was explained before. The point on which the rod is held is called a "turning point," and any hard, definite point that will not be destroyed until the leveller has found his elevation again will answer very well; for instance, the top of a stake, if it is solid, the top of a hub, a point on a stump, etc.

But cases will occur when nothing of that kind can be found where the instrument can see it, and then a turning point must be made.

The usual plan is to make a little peg about an inch in diameter and about six inches long, and drive this solidly into the ground, leaving about $\frac{3}{4}''$ or $1''$ sticking up.

Another trick is to drive the hatchet into a log of wood, or something, so that the back of it is horizontal, and then turn on that, but in this latter case be careful not to move the hatchet.

When a turning point has been chosen, before using it mark it with a small cross, and then if your attention is called off you will not be puzzled when you come back to know which of half a dozen points you thought of you really did use.

In case of accident, it is well to leave the turning points in the ground, so that they may be found and used again, and it is partly for this reason also that they are marked with a cross.

Of course one cannot go back and stick the hatchet in just exactly as deep as it was before, and therefore it should be used as a turning point as little as possible.

As readings at turning points must be taken with extreme accuracy, and as the rodman, no matter how careful he be, cannot judge when the rod is exactly plumb, it is customary to "swing" or "wave" the rod backward and forward on all turning points, for in one of the intermediate positions the rod must be plumb.

To do this, get a firm footing behind the rod, and setting the rod on the turning point lean it well forward, and then draw it slowly backward, bringing it well behind the plumb position, then wave it slowly forward again, and repeat this until the leveller signals you that he has the reading.

Beside these duties of the rodman in the field, he has also to "call" the profile in the evening; that is, he calls out the elevations of the stations, and the leveller plots these on paper prepared for this purpose. As different levellers like the profile called in different ways, no details of this part of a rodman's work would be of any use.

The points then, to which a rodman on survey or location has to give his attention are:—

First, to hold the rod plumb: always to call the number marked on the stake; to take "pluses" at all prominent points where the ground changes to any considerable extent; to choose solid points as turning points, and mark them in such a way that there can be no doubt as to the point on which the rod was held; to cut and mark all bench marks neatly, and if possible to put them in such positions that they can be seen from any part of the line near them; to inform the leveller of any error in chainage or marking of the stakes that may be noticed; and, lastly, to call the profile for the leveller in the evening.

## II. RODDING ON CONSTRUCTION.

On survey we have been getting information to enable the engineer in charge to choose the best line. On location we have laid down the line chosen, the methods used being similar to those used on survey, and on construction we prepare the work for the contractors.

To do this, the work is divided, as was explained before, into "divisions," and these divisions sub-divided into "sections"; there being an engineer for each division, and an engineer with his rodman and axeman for each section.

The first thing an assistant engineer does upon going on to his section, is to run check levels over the whole of it; that is, he runs very carefully over the line, checking all the bench marks, and putting in new ones wherever he thinks they are necessary, and also checks the levels of the centre stakes if he thinks necessary.

If there be any doubt as to the alignment, he should also check it by running over it with the transit; but as the location is usually made with great care, this is very seldom necessary; but the check levels are usually run on account of the ease with which a mistake can be made in reading the rod, or in noting the reading in the level book.

As constant reference must be had to bench marks, both in running check levels and in the ordinary work on construction, a good plan is for the rodman, before going out on construction, to get a list of all bench marks from the engineer, and carry them with him constantly, so that no time will be lost in finding them.

For the same reason this might also be done in the case of hubs, for although the engineer usually has a list of bench marks and hubs with him, yet in case of the rodman's being some distance from him, or if by chance he has not his list with him, a good deal of time and trouble would be saved by the rodman's list.

After the check levelling and alignment are done, the real work of construction begins. This consists in first laying out the right of way, and the clearing in all bush on the line; then the amount of cut or fill at every station must be marked for the contractor, and stakes set to mark where the embankment or cutting will meet the natural surface of the ground; and, finally, stakes must be set to mark the openings to be left in embankments for culverts, drains, etc.

Plans come from the head office giving the width of each owner's land which the company propose to buy; this is called a plan of the right of way, and the widths shown on the plan must then be staked out in the field.

In staking out the right of way, stakes about $4\frac{1}{2}'$ or $5'$ long, $1\frac{1}{2}''$ broad and $1''$ thick are used. These stakes are set so close to each other that from any one those next to it on either side can be distinctly seen. They are usually set opposite a full station or hub, the distance of the fence line from the centre stake being measured with a tape, and the stake set in at right angles with a pocket sextant. When the stake has been driven solidly into the ground on the face next to the centre line the word "FENCE" is printed with chalk, and below it the distance of the fence stake from the centre line is marked thus, "FENCE, 50′ S."; the letter S standing for South, and meaning the fence line is fifty feet south of the centre line at that point. A similar stake is then set on the opposite side of the line, and marked similarly with the word fence and the distance and direction of the fence line from the centre line.

In cases of jogs in the fence line, two stakes are set at the station where the jog occurs, the one denoting the end of one line of fence, and the other the beginning of the other line.

When the line runs through bush, the right of way is cleared to its full width, of course; and so in marking the stakes, they are marked "CLEARING, 50′ S.," instead of "FENCE," etc., as in the open.

The right of way and clearing are usually staked out first, in order to let the contractor get his clearing gangs to work as early as possible, and while the clearing is being done the earthwork in the open parts of the line is usually laid out.

In laying out work, as it is called, it is customary to stake out only the full stations, but also to cross-section such "pluses" as the engineer thinks necessary; the cross-sections being taken to get the quantities as accurately as possible, and the stakes set to show the contractor where the edge of the cut or fill is. In some cases engineers prefer to cross-section every fifty feet, that is, the full and half stations; but unless there is some apparent change in the surface, this is hardly necessary, although in any case it can do no harm and may make the quantities more correct, at the expense of a great deal more work.

Since the quantities which the contractor moves are measured in the cuts, pluses will be much more frequent and necessary in cuts than in fills; in fact, they need only be given at pretty abrupt changes in fills.

The first thing to be done in laying out a station is to get the cut or fill, and as the surface of the ground is somewhat indefinite, it is customary to drive a small plug, about 5″ long and $\frac{1}{2}$″ in diameter, behind the centre stake, and to hold the rod up on that. The rodman calls out the number of the station, and the engineer, reading the rod and knowing his height of instrument, finds the elevation of the top of the plug. He also knows the elevation of grade at that station, for he has given in his profile book the height of grade at the last point at which it changed, and also the rate at which it is rising or falling. He can then see the relative elevations of the ground and grade, and calculates the amount of the fill or cut by subtracting the elevation of the ground from that of grade for fills, and *vice versa* for cuts. This calculation is made to the nearest tenth and the result called out to the rodman, who marks it on the back of the centre stake, thus, "C. 6.9" (or) "F. 5.7," the numbers always being marked so as to read downward.

Here it may be said that it is always advisable for the rodman to repeat the number which the engineer has called to him, and thus prevent any mistake in his hearing the number.

If the instrument be above grade, a neat method of calculating a fill is for the engineer to subtract the elevation of grade from the height of instrument, and then when the reading is taken he has merely to subtract this difference from it, and he gets the fill. If, however, the instrument be below grade, the H.I. is subtracted from the elevation of grade. and then when the reading is taken, by adding this difference to it the fill is obtained.

In cuts it is evident that the H.I. must always be above grade, and the elevation of grade is then subtracted from the H.I., and when the reading is taken it is subtracted from this difference, and the cut thus obtained. These methods save a little time, for the difference between the elevation of grade and the H.I. can be found while the rodman is going from one station to another; whereas, in the ordinary method, nothing can be done until the reading is taken. The cut or fill having been found and marked, the next thing to be done is to "lay out" the station; that is, to put in the "slope stakes," which denote the point where the slope of the embankment or excavation will meet the natural surface of the ground, and there are two methods of doing this.

The first method is by cross-sectioning every station and plus, after having found the cut or fill; then going into the office and plotting the cross-sections on cross-section paper, and by drawing in the depth of cut or fill, the width of the roadbed and the slopes, finding the points in which those slopes intersect the surface of the ground and the distance of such points from the centre line. A list is then made of these distances, the section is gone over again and the stakes set in. This method saves some time and is perhaps less troublesome, for the cross-sections have all to be plotted anyway.

The second method is by staking out every station as it is cross sectioned ; perhaps it is the slower and more troublesome method, but it is the proper method, and the way in which most chief engineers require the work to be done ; for an error in the plotting, in the first method, would cause an error in the placing of the slope stake, and, besides this, it is not considered business-like.

In the first method the rodman gives the centre sight, marks the cut or fill as the engineer calls it, and the axeman, holding the tape at the centre stake, the rodman pulls out and gives a sight at every point where the ground changes even slightly, calling out in feet and tenths the distance from the centre stake of every sight he gives, and going out until the engineer stops him. He then does the same with the other side of the line, and between the stations watches for pluses, at which he puts in centre stakes, marks the cut or fill, and cross-sections.

The engineer and rodman go into the office, plot the cross-sections and take out the quantities ; the axeman, in the meantime, being out on the line making stakes. When the plotting is finished and a list of all slope-stake distances made out, they go out into the field and put in the stakes at the given distances and always at right angles to the centre line.

In the second method the rodman gives the centre sight and calls out the number of the station ; then marks the cut or fill, and the axeman holding the tape at the centre stake, he pulls out (giving sights as before) until he comes to the point directly over or under the edge of the roadbed, where he always gives a sight. The slope being given by the proportion of the horizontal to one vertical, the engineer calculates the horizontal distance corresponding to the cut or fill at the edge of the roadbed, adds it to the half width of the roadbed, calls out the result to the rodman, who pulls out to that distance—giving sights where necessary—and gives a sight. The engineer then makes a correction for the difference in elevation of this last point and that at the edge of the roadbed, and calls out the horizontal distance as before, with this correction added or subtracted, and the rodman moves to that distance and gives a sight. The engineer makes a similar correction to the first and calls out the corrected distance to the rodman, who moves again and gives another sight. These two corrections are usually enough, but in very rough ground more may be required ; if so, they are made in exactly the same manner as the other two. When the required point has been found, a "slope stake" is driven in to mark it. These stakes should be 15″ to 18″ long, about 1½ inches broad and 1″ thick. The broadest faces of the stake are "blazed," and one side is marked the station and on the other the letters "S. S.," slope stake, and the distance from the centre line.

The stake should be driven in plumb, with the side bearing the letters "S. S.," etc., facing the centre stake. The next points that must be marked for the contractor are the "grade points" ; that is, those points where the cut runs out and the fill begins, or *vice versa*.

These points are marked by putting in three plugs at grade; one on the centre line, and one on each side at the edge of the roadbed.

When the engineer finds that the cut is getting very small, he calls or signals to the rodman to find grade. The rodman, knowing the cut or fill at the last station, moves down or up the incline, (along the centre line) until he thinks he is about grade. He then calls out "grade," and gives a sight. The engineer motions him up or down until the rod-reading shows that the rod is resting on grade. when the rodman is signalled "all right." A "grade plug," as it is called, is then driven at this point. This plug is about 1½″ square, from 6″-8″ long, and has a good, hard, unfrayed top. It is driven until it is slightly above grade, and then by means of successive sights and tappings, it is brought down exactly to grade. To mark this plug, a stake, called a "grade stake," is driven in in front of it, bearing on its face the number of the station and the plus, and on the back the word "grade," reading downward, and marked directly over the plug. The plus of this grade point is called to the engineer, and the axeman holding the tape at the centre, the rodman pulls out (at right angles) to the width of the roadbed, and choosing the point which he thinks is on the same level as the plug just set, he gives a sight. He is motioned up or down, as before, until he finds grade, where a plug is driven and set, as at the centre. Behind this plug a grade stake is driven, and on the front of it, above the plug and reading downwards, the words "GRADE ON PLUG" are marked, and a similar plug is then set on the opposite side of the line. If the plus of either or both of these points differs from the plus of "grade at centre," it must be found and called to the engineer. As the work is gone over it is customary to take the "hub stake" from its place at the side and drive it directly behind the hub; and then to put in stakes on each side at about 20′ or 25′ out, as "reference stakes." These stakes have their inner faces blazed, and marked with the word "HUB," the number and plus of the station, and the distance and direction of the hub from the reference stake, thus:—"HUB, 337 + 27.5, 20′ S" These stakes, of course, form no permanent reference for the line, but are merely useful to find the hub when the "hub stake" has been lost, and before the earthwork has been commenced.

For permanent referencing, the methods described in Mr. Kennedy's paper are the proper ones to use. The openings to be left for drains, culverts, cattle-guards, etc., must also be marked for the contractor; and small drains, such as tile drains, may be staked out in the following way:

The point on the centre line at which the drain is to be put in having been decided upon, a stake is driven in, having on the face the number of the station and the plus. A sight is then given on the ground behind this stake, and the cut is calculated and called to the rodman, who marks it on the back of the stake. Two stakes, blazed on opposite face, are then set in on the centre line, before and behind the stake already set, and having between them the width of the excavation for the tiles. On the outer faces of these stakes the word "DRAIN" is marked, and on the inner faces the cuts are marked, they having been found by sights given at each of the stakes.

Then, two stakes corresponding to the last and similarly marked are set at the side of the line beyond the edge of the embankment; and two other similar ones are set on the opposite side of the line; making a total of seven stakes for marking a drain.

All plans for culverts and cattle-guards are made up at the head office and sent out, but the engineer, in going over the line laying out, merely puts up a large stake with something like the following on it:—

"8′ OPENING FOR CULVERT."

the culvert being laid out afterwards when he has the plans.

Besides laying out work as he goes over the line, the engineer puts in hubs to keep the alignment. These hubs are set in the usual way (the rodman doing the picketing), about 8/10 below grade, and reference stakes, as described, are driven in on either side.

The hubs should be extra long, so that they will not be disturbed if kicked or tramped upon by the horses, and should be driven rather low so that the scrapers will not catch them.

Such, then, are the duties of the rodman in the field, but in the office he has also to assist in taking out quantities, checking the level book, and in the general work of the office.

On construction, then, the rodman has first to rod for the check levels and picket for the alignment, if it is run. In running check levels the greatest possible accuracy and care are necessary; but besides this, the rodman must be sure to check *every* bench that has been put in on location. Next comes the staking out of the .clearing and of the fence line; the point in this being to get the stakes set at the proper distances, exactly at right angles, and driven solid and plumb.

In rodding for laying out work, the saying that one should "always give the contractor the benefit of the doubt," will convey some idea of the degree of accuracy necessary in cross-sectioning, and the number of pluses necessary between full stations. In the picketing, the main idea is to get the hubs where they will not be disturbed by the navvies, but as that is pretty difficult the line is usually referenced at the side and altogether away from the line of haul of carts, scrapers, etc.

In the office work the rodman cannot be too careful, for he is dealing almost altogether with numbers, and we all know how easy it is to make a slip in the simplest calculation.

GEO. H. RICHARDSON.

# EXPLORATIONS ON THE BATTLE RIVER.

*Mr. President and Gentlemen:*

It was on the afternoon of July 17th, 1885, that our little party bidding farewell to the Calgary-Edmonton Trail, turned its back to the setting sun, and being assured that all our necessary outfit was securely stowed away in our canoe, started on our long voyage down the Battle River. It is so called, I was told, from its being many years ago the scene of one of the bloodiest battles between the two great Indian nations of the North-West Territories—the Crees and the Blackfeet. It takes its rise in that immense swampy region surrounding Pigeon and Battle Lakes, about 150 miles north of the Canadian Pacific Railway, and 80 miles from the Rocky Mountains. Between its source and the Rockies, flow the Saskatchewan to the north, and the Red Deer to the south, intercepting all mountain streams, and compelling the Battle to be purely of prairie origin. But the low-lying boggy district surrounding its head waters, into which the surveyor can penetrate only when winter's frost has formed for him a solid footing, is of itself quite sufficient to produce a large river.

After flowing through about 350 miles of valley, it enters the Saskatchewan at Battleford, and by way of Lake Winnipeg, and Nelson River, its waters flow into Hudson's Bay.

The object of our journey was to make a geological, as well as geographical examination of the river and surrounding country, between the limits of the fifth and fourth principal meridians. The upper half of this distance had, during the summers of 1883 and 1884, been traversed by Dominion Land Surveyors. but the lower part was as yet comparatively unknown. But notwithstanding the work already done in the two previous summers, on account of the recent government maps not being completed, we were obliged to keep a tract survey so as to be able to locate exactly where any minerals or fossils were found, or where a new geological formation occurred.

Before going further on our journey, it may be interesting to review the general method of work.

In the first place then, the instruments used were but few and simple. They consisted of a prismatic compass, with a three inch card, an ordinary watch marking western standard time, and an aneroid barometer. Note books, scale and protractor were also used, and the country plotted as we proceeded. The prismatic compass was preferred, for since a bearing is seldom taken to less than half a point, results just as satisfactory will be obtained, as if the instrument had been the regular surveyors compass. A watch also proved of great assistance, for since the average rate of our canoe was known—about 3½ miles per hour—distances could be estimated tolerably well. The note books supplied by the Government to their geologists, seemed to me especially suitable. They are of such a size as to fit into an ordinary coat pocket without difficulty, viz.: about 5 ″ x 8.″ The pages are divided into blocks ½″ square, so that the paper itself is a scale. One page was used for the tract survey, the other for written descriptions of the geology of the country, so that every two pages indicated one days work. Now as the start was made in the morning, the plotting of the country would be commenced in the usual way at the bottom of the page. A bearing taken would be laid off with the protractor, and the estimated distance by scale. Neighboring hills, lakes, streams, etc., were noted in the same way, so that by evening the page of our note book would be an approximately correct map of the country passed over during the day.

On being sent to the government, the leaves are all cut out of these books and pasted together, and with a pantograph, reduced or enlarged to any desired size.

It is in this way that the maps of the geological survey are produced.

But let us return again to our original story.

At its crossing with the fifth principal meridian, and about twenty five miles from Pigeon and Battle Lakes, the river has gained a width of nearly two chains, a depth of eight feet, and has a flow of about two miles per hour. Its water is of a darkish color, owing partly to the muskeg country surrounding its head-waters, and partly to the large quantity of clay iron stone found in this region.

On the afternoon of the second day, as we floated down the stream, we noticed on the high right bank, a small log shanty, and from its general appearance its square fences etc., we concluded that its occupant was no Indian or half-breed, but a white man. On climbing the hill, and making our way to the door, we were kindly greeted by the missionary to the Stoney Indians, who was busily engaged in repairing and rebuilding his house after the Indian raid of a few weeks before. He had, we were told, only left a few days with his family for a place of safety, when Bob Tail and his band came along, pillaged his house, drove his horses and cattle away, and after exhausting their means of destruction, rode off leaving the place a total wreck. During our stay here, Samson, a friendly chief, came over to the missionary telling him to make no more repairs, for he believed, that later on in the fall there would be a general rising of the Indians in the North-West. It was talked of, he said, not only in their own tribe, but also among the Crees and the Blackfeet. Another Indian came a few hours later bearing the same startling intelligence. The prospect now of starting with so small a party after the news which we had just received, to penetrate the heart of a hostile country, did certainly not seem the most inviting.

Later in the evening of the 20th, we reached the shore of a small lake, in a cold and drenching rain. The night was dark and dreary, and the continuous howling of prairie wolves did not tend to make it any brighter. By the light of a small fire of wet wood, we pitched our tent, not, however, without some trouble ; for hunting about in black darkness in a bush, now tumbling head foremost over a pile of logs ; then running against a standing tree ; at the same time wet and shivering, and as yet without tea, could hardly be called revelling in luxury and ease.

This lake is about two miles long, and although very shallow, acts as a settling pool for the river. So that the apparently dirty water which comes in, flows out again clear and sparkling. Six miles below this lake is Todd's crossing, a small half-breed settlement of some half-dozen families, all of whom depend for a livelihood upon fishing.

The method these Indians use for catching fish seemed to me at first, cruel and inhuman. Two lines of closely set stakes are driven into the river bottom forming the two sides of a triangle, vertex down stream. One of these sides is made shorter than the other, so that the point can be easily reached from the shore. At this vertex is a gap of about four feet, in which an inclined plane formed of poles is placed, the high end down stream, and about a foot beneath the surface of the water. Both the fence of stakes and the inclined plane are open enough to allow water to pass through without being much dammed, but all fish except very small ones are retained. Around this gap, on the outside, is worked a large basket of willow boughs, so that all fish coming down the river are forced through this gap, and caught in the basket. The night we were there this trap caught about a ton of fish, principally gold eyes, suckers, and jack fish, having an average length of about eighteen inches.

The valley of the Battle throughout its entire course, varies from half to two miles in width, and this distance is for the most part a low flat, overgrown with poplar, spruce and willows. In this wide valley the river meandered backward and forward in tortuous windings, so that often after hard paddling, we would find ourselves only a few rods from where we were an hour or more before. Wherever the turns in its course are sharp, the current-side of the bank is, of course, worn away, so that trees and bushes having their foundations swept from under them, fall into the river, forming a barrier there. When nearing just such a place as this on the evening of the 22nd, we paused for a moment, fearful of the boiling rapid ahead, but in a second were whirled on, and in spite of our exertions with the paddles, were carried down in the strong arms of the current and dashed a helpless wreck against a mass of projecting bushes ; our all was lost. We could speak for nothing more than for ourselves. However, our position was a serious one, so that we immediately set about saving our baggage. Some of the lighter things which would float, we had secured before nightfall, the rest were we knew not where. Our supper that night, was novel, in fact it seems rather more so now than it did then. It consisted of oatmeal porridge, void of all seasoning or sweetening, served up in the pot—the only cooking utensil saved—and eaten with a flattened stick. Never before did a meal taste so dainty or delicious.

Without a dry stitch in our outfit, or a single weapon for protection, we laid ourselves down on the river's bank, and before long were fast asleep.

Next day, chiefly through the exertions of one of our party who was an experienced diver, many things were found, and the following day many more; so that on the third day after our misfortune, we were again started, to make the fastest time possible for the nearest village where we could procure more supplies.

On reaching Salvay's Crossing,—also a half-breed settlement,—we found most of the men away, among others the owner of the ferry. On inquiring we were told that he was visiting in Edmonton ; visiting, however, rather from necessity than from choice, at the Edmonton jail, to account for his actions at Batoche during the late rebellion.

A little above the village is the mouth of the Pipestone River, and from the high bank the view we had was very interesting. The Battle although more than four times as large as the Pipestone, has a valley only a quarter as wide.

After their junction the narrow valley disappears, and the Battle continues in the valley of its tributary. From my position at the top of the hill, the little coulée entering away in the distance, looked as if some little stream might be running there instead of our mighty river.

During the past several days great numbers of geese and ducks had been seen, not a few of them being obliged to stay with us, which helped considerably to "vary the stereotyped fare of Government bacon."

Our latitude was now 53°, the highest point we had yet reached, being about 700 miles further north than Toronto. In June, at this place, ordinary print can be easily read at 10 o'clock in the evening.

During all this time, the peculiar appearance of "*buttes*" had been attracting our attention. These are great mounds of earth rising immediately from the valley, and formed by the continuous action of the river on a narrow isthmus, which in the end it succeeds in wearing a passage through, leaving what was before a high ridge stretching out into the valley, now a lonely mountain. As they are of different shapes and sizes, so also are they different in beauty. Some in the form of cones, tower up from the valley a height of from two to four hundred feet. Others, wedged shaped, are so prettily formed, that they look like the roof of the palace of some ancient god. One, my barometer showed to have a height of 450 feet.

At the Government "cache," at the most southerly bend of the river, the view we had was really entrancing. What land is to a weary sailor, or water to a traveller in the desert, so was the sight of the expansive prairie, after travelling for weeks in the narrow valley. Standing on the summit of an almost perpendicular wall of ground, 250 feet above the valley, behind us lay the prairie, flat and boundless as the ocean, and in front, the beautifully wooded valley of the Battle, the river winding tortuously among its knolls and buttes ; appearing here and there like a silver band, and then fading away in the tree tops.

A picture with more beautiful contrast could not be imagined.

Passing on from here, in about twenty-five miles, we came to a narrow valley where, on account of being thus corraled, the river was obliged to straighten in its course. At one time we were able to take a sight of three quarters of a mile, and at another a mile, the latter being the longest we had yet taken.

The river still maintained its flow of two miles per hour, although its width had now increased to three chains.

After passing in succession Grizzly Bear, and Blackfoot coulées, both entering from the north, we reached the old Fort Pitt and Sounding Lake Trail, where our story closes.

It was now the 19th of August, and the first white man's voyage down the Battle River was at an end. We had been on the way thirty-two days, during which time we had come, including the river's diversions, over 700 miles.

H. G. Tyrrell.

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# MORTARS AND CEMENTS.

*Mr. President and Gentlemen,—*

In this paper on Mortars and Cements, I shall not endeavor to dwell at any length on any particular part of their manufacture or use, but shall take up the subject as a whole.

The material generally used in the manufacture of lime is the carbonate of lime, which is the constituent of bone, shells, etc., and is the principal ingredient of all natural limestone.

It will be necessary here in the beginning to explain the processes employed in the burning of the lime, which is effected in (1) kilns ; (2) in mounds and ovens. There are two kinds of kilns in which the lime is burnt.

(*a*) The intermittent or ordinary way.
(*b*) The continuous kiln.

The first of these is the method usually employed in localities where the burning cannot constantly be carried on, and is too familiar to require any explanation.

In the continuous kiln the lime is burnt either in kilns in which the fuel (generally coal) and stone are placed in alternate layers, or in kilns in which the fuel and stone are not in contact.

In the first of these the actual burning space is in the shape of an inverted cone, wide at the top and narrow at the bottom.

In the latter the kiln retains its character as a perpendicular or shaft kiln, but the fuel instead of being interstratified with the lime-stone is burnt in separate hearths in the side of the shaft, and the flame is conducted into the latter, which in this case contains nothing but the lime-stone to be burnt. In burning in mounds, which is done in Wales and Belgium, the fuel and lime-stone are put in a circular kiln and covered with turf, making a pile of about 16 feet in diameter at the base and 12 feet at the top, the burning occupying from 6 to 7 days.

In the slaking of lime there are three methods in common use :—

(1) Drowning.
(2) Immersion or sprinkling.
(3) Spontaneous slaking.

The first and second methods will probably explain themselves, while in the third method the lime is slaked by exposure to the air, from which it absorbs moisture, for which the lime has great affinity. Mortar is a mixture of slaked lime with sand in different proportions, in which the lime is to be good, and the sand good, sharp, and angular.

The proper proportion of sand and lime is a most important point in preparing mortar ; as a general rule, the lime should be sufficiently fine to cement all the grains of sand together. The surfaces of the grains of sand, or the voids between them should be only just covered with the lime in a semi-liquid state, and therefore enough lime should be added to fill up the voids in the sand without increasing its volume.

Both the sand and water should be free from clay and salt ; sea-shore sand should not be used as it is almost impossible to get rid of the salt, and enough will generally remain to keep the work damp and to produce an efflorescence of nitre upon the surface of the brick, whether with lime or cement mortar. Common mortar exposed to moisture may be seen to be rotten or to have become useless, and if exposed to a constant moisture will never harden properly. Thus it becomes necessary to use some mortar which will stand the moisture, generally.

*Hydraulic Mortar*, which is made from a lime containing more than 10% of silica and alumina, which imparts to this mortar the peculiar property of hardening under water has thus very appropriately received the name hydraulic. Moistened hydraulic lime is at first a very soft friable mass, which is easily scratched by the nail, but when covered with water it acquires a hardness which is quite equal to and often exceeds that of the limestone itself, for which it is often used as a substitute. As a general fact the time in which the hydraulic limes become hard is very variable, and the chemical action which is the cause of the hardening, is consequently very unequal.

The degree of hardness which they acquire is also not the same, those that harden slowly being often more compact than those that harden in a short time. The time required for hardening varies from a few minutes to weeks and months, and bears some relation to the amount of aluminous matter present in the lime. The more the lime contains of this ingredient the more quickly it hardens ; thus, in a lime containing silicate of alumina in the proportion of from 6 to 8 or 12%, the lime becomes simply "moderately hydraulic," and sets in from 15 to 20 days ; when in the proportion of from 12 to 20% it is called "hydraulic," and sets in from 6 to 8 days, and hardens in about 6 months, while that containing from 20 to 30% is called "eminently hydraulic" lime, setting in from 3 to 4 days and hardening in 1 month, and at last slowly approaches the character of the cements.

Hydraulic mortars do not require sand, but it is used for economy as it does not seriously impair the value of the cement, if used in moderate quantities, and even 1½ of sand to 1 of lime does not impair its value.

The hydraulic mortar employed by Smeaton in building the Eddystone light-house consisted of equal quantities of lime slaked to powder, and pozzuolana, a product of volcanic origin used very much by the Romans in the manufacture of their mortars. Good hydraulic mortar should not show any tendency to crack when hardened under water, even when no sand is mixed with it.

If the mortar is not only required to harden, but also to bind well, it is necessary that the surface of the stone shall be moistened, when this is not done the surface of the stone (by the power of absorbing moisture) dries the mortar, and prevents proper adhesion from taking place. As in common mortars, the grain of the sand employed requires to be sharp and angular; and it is better to use a mixture of coarse with fine sand, than that the sand should be all of the same sized grain.

The hydraulic limes which we have been considering are those which slake with water and have the power of setting under water. Certain limestones when burnt will not slake with water, but when the burnt stone is finely ground and made into a paste, it also has the property of hardening under water, and to distinguish it from our hydraulic mortar is called hydraulic cement.

A few natural cements are found and may be considered as chiefly of volcanic origin, chief of these is the pozzuolana which has been already mentioned, and received the name from the village of Pozzuoli in Italy, near which place it is found.

The use of the natural cements is the exception and not the rule, for on account of their high price, consequent upon the smallness of the quantity found, the use of artificial cements has almost superseded their use.

The earliest known artificial cement is that manufactured by Parker, Wyatt & Co., who took out their patent in 1796. The cement prepared by them and still in use is known as English or Roman or "Parker's Roman," and was manufactured by burning clay nodules, known as "septarian nodules," found in a peculiar clay-shale, above the chalk formation of Isle of Sheppy and the Isle of Wight, and elsewhere. The composition of the nodules is approximately clay 33%, carbonate of lime 67%.

They are burned in the ordinary conical kiln with coal or coke as fuel, at an under heat, to prevent vitrifaction. They are afterwards pulverized, and as the resulting red-brown powder eagerly absorbs carbonic acid and water from the air, it is necessary to keep it in air-tight casks, in which form it is sold in commerce.

This cement has a close fine grain, pasty look and greasy feeling, and loses $\frac{1}{3}$ by weight when burning. When made into a mortar it sets in from 15 to 20 minutes.

There are four kinds of artificial cements :—

(1) Twice kilned artificial cement.
(2) Portland cement.
(3) Artificial pozzuolana.
(4) Silicization cements.

In the first the process of making the cement is to take clay of 50% alumina, and 4 to 5% of carbonate of lime ($CaCO^3$).

The clay is first burned until every trace of moisture has been expelled and it is then thoroughly mixed with the lime. It is then dried in the open air in sheds; then made into balls of 2 or 3 inches diameter and burned at a red heat; then again ground into a powder, after which it is ready for use.

Portland cement is named from the resemblance to the Portland stone, and is a scaly crystalline powder of grey color.

This cement was first prepared by Mr. John Aspdin, of Leeds, England, and was prepared by him in the following way. A large quantity of limestone is taken and pulverized, then dried and burnt in a lime-kiln. An equal quantity, by weight, of clay is then added to the burnt lime and thoroughly kneaded with water until a plastic mass is formed. This is afterwards dried, broken in pieces, and burnt in a lime-kiln to remove all the carbonic acid. The mass, now in the form of a fine powder, is ready for the market, and is known in commerce as a grey, or green-grey, sandy, palpable powder.

This cement was manufactured by Paisley in 1826 by burning river mud from the Medway, impregnated with the salts from the sea water, with lime-stone or chalk, and at the present the mud from the mouths and delta formations of several large rivers is employed in the preparation of this cement.

In the manufacture of Portland cement the following mode is generally followed. The raw materials, limestone and clay or mud in equal quantities, are intimately mixed; the mixture dried in the air, and then burnt in a shaft oven, such as is used in burning the lime, which has already been spoken of. The oven is so arranged that a layer of cement stone and a layer of fuel alternate; the fuel being generally coke, as this has been found by experience to be the best adapted for the purpose. After the mass has been submitted to a red heat for one hour it assumes a yellow-brown color, and at a higher temperature becomes a dark brown. Gradually the lime enters more and more into chemical combination with the silicates, at a white heat or at a temperature of about 1600° C; the mass becomes grey in color with a streak here and there of green. If during the operation of burning, these colors are shown at the several stages, the resulting cement will be good and set hard. If the heating is continued above the white heat or 1600° C, the cement will become quite useless and is very similar to glass-powder.

The more lime the mixture contains the more durable is the cement, and the less it falls to pieces in burning, while a cement with clay predominating is a weak cement, falling in pieces readily or not binding well.

The more intimately the clay and lime are mixed the larger the amount of lime that can be incorporated, and hence the better the resulting cement.

The cement, if set in air, exhibits no change from the stiffening until the final hardening, but if in water, there is at first a small loss of the more soluble constituents—the alkalies.

Portland cement mixed with water to a pulp, stiffens in a few minutes, and after the lapse of a day sets tolerably hard. After a month the cement sets into a substance so hard and firm that it emits a sound when struck by a hard body, and has received the name of "artificial stone" from its capability of being cast into various architectural ornaments, etc.

The manufacture of true Portland cement is confined, by letters patent, to England alone, but various kinds of Portlands are manufactured in America, Germany, and other countries; but none of these are as good as the English Portland.

The comparative values of the different cements may be had from their costs, which are as follows :—

| | | | | |
|---|---|---|---|---|
| English Portland cement... | $2.80 to $3.25 | per bbl. | of | 400 lbs. |
| The German Portland....... | 2.70 to 3 00 | " " | " | " |
| Saylor's American cement.. | 2.50 to 2.75 | " " | " | " |
| Rosendale................ | 1.60 to 1.80 | " " | " | " |
| Other U. S. cements....... | 1.35 to 1.60 | " " | " | " |

The Portlands are generally sold in barrels of 400 lbs. gross, while the Rosendale and the ordinary United States cements are sold in bbls. of 300 lbs. gross.

Protection from moisture, even that of the air, is very essential for the preservation of cements as well as of quick lime. On this account the barrels are generally lined with stout paper. With this precaution, aided by keeping the barrels stored in a dry place, raised above the ground, the cement, although it may require more time to set, will not otherwise appreciably deteriorate for six months; but after 14 or 16 months, Gillmore says, it is unfit for use in important works. Restoration by reburning may be effected by spreading the injured cement in a thin layer on a red-hot iron plate for about 15 minutes, when its good quality will be in a great measure restored. If it has actually been wet or lumpy, or cemented into a mass, it should first be broken into small pieces and then ground, or these pieces may be first kiln-burned at a bright red heat for about 1½ hours and then ground. A barrel of cement, 300 lbs; and two barrels of sand, mixed with about $\frac{1}{2}$ barrel of water, will make about 8 cub. ft. of mortar, sufficient for :—

192 sq. ft. of mortar-joint $\frac{1}{2}$ inch thick = $21\frac{1}{2}$ sq. yards.
or, 288 " " " $\frac{3}{8}$ " " = 32 "
or, 384 " " " $\frac{1}{4}$ " " = $43\frac{2}{3}$ "
or, 768 " " " $\frac{1}{8}$ " " = $85\frac{1}{3}$ "

The common (not Portland) cements when used as a mortar for brick work often disfigure it, especially near sea coasts, and in damp climates, by white efflorescences which also injure the bricks. This is usually a hydrous carbonate of soda or of potash, often containing other salts, and as a preventive Gen. Gillmore recommends adding to every 300 lbs. of the cement powder, 100 lbs. of quick lime, and from 8 to 12 lbs. of any cheap animal fat, the fat to be well incorporated with the quick lime before slaking it preparatory to adding it to the cement. This addition will retard the setting and somewhat diminish the strength of the cement.

Color is no indication of strength in hydraulic cements. The finer they are ground, however, the better, and at least 90% should pass through a sieve of 50 meshes per lineal inch or 2,500 meshes per square inch.

The term setting which we have been using does not imply that the cement has hardened to any great extent, but merely that it has ceased to be pasty and has become brittle. Slow setting does not indicate inferiority, for many of the very best are slow setting. The time required to attain the greatest hardness is many years, but after the first year the increase is usually very small and slow, and there seems to be a period (from a few weeks to several months after having been laid) at which the cement and its mortars, for a short time not only cease from hardening, but actually lose strength ; they then recover and the hardening goes on as before.

This phenomenon is rather strange, but is the result of experiment and has been confirmed by good authorities.

The fourth kind of artificial cement is the silicated, and consists of the silicates of potassium or sodium, with lime. It is formed by boiling flint with KOH, under pressure of 70 or 80 lbs, which gives a soluble glass or liquor of flint, and this on evaporation yields a scaly horny mass. When mixed with CaO, it forms a double silicate.

This cement constitutes the class of artificial stones used for mantles, table tops, etc.

Strength of cements. The methods used in testing the cements are as follows :—

(1) Testing their resistance to tension.
(2) Testing their resistance to penetration.

For this purpose the cement is made into blocks about the size of a brick, and for the first test they are drawn apart by a machine ; for the second test the blocks are rested on some stable body and a force is applied to break it in the middle, and the breaking force is recorded.

The strength of the cement is very much affected by the temperature of the air and water, as also by the force with which the cement is pressed into the moulds, and by the extent of setting before being put into the water. These causes, together with the degree of thoroughness of mixing or gauging, the proportion of water used, and other considerations, may easily affect the results 100%, or even more; hence the discrepancies in different experiments. After only 24 hours in water the strength of the common U. S. cements average about half that for 6 days. The London Board of Works require that Portland cement after 7 days in water shall have at least 35 lbs. transverse, and 350 lbs. tensile strength per square inch. Mr. Shedd, as Engineer of the Water Works and Sewers of Providence, R. I., rejected all Rosendale, which when mixed to a stiff paste, and allowed 30 minutes in air to set, and then put into water for only 24 hours, broke with less tension than 70 lbs. The Sewer Department of St. Louis required all Louisville, Kentucky cement to bear at least 40 lbs. tensile, after 24 hours in water. Some of it showed as high as 100 or more, and 60 or 70 would have been adopted as a minimum, but for the fear that it would encourage the making of too quick setting cement. Most of that sold will probably not exceed 30 lbs.

The following is the analysis of two modern cements :—

| DESCRIPTION. | LIME. | $SiO_2$. | $Al_2O_3$. | $Fe_2O_3$. | ALKALI. | CLAY & SAND. |
|---|---|---|---|---|---|---|
| Roman cement used in Eddy-stone lighthouse | 55 | 25 | 8 | 5 | 5 | 2 |
| Portland cement. By Michaelis............ | 59—62 | 24–25 | 6—9 | 3—5 | 4—5 | 1—2 |

And again the analyses of some very old cements are as follows:—

| LOCALITY. | AGE. | $CO_2$. | Ca O. | $SiO_2$. | SAND. | WATER. | ALKALI. |
|---|---|---|---|---|---|---|---|
| Brandeburg Cathedral... | 600 | 5.00 | 8.70 | 1.25 | 83.75 | 1.20 | —— |
| St. Peters, Berlin....... | 600 | 1.75 | 9.25 | 3.75 | 78.50 | 6.75 | —— |
| Roman Well at Cologne. | 1800 | 9.00 | 15.00 | .27 | 68.00 | 4.00 | 2.75 |
| Roman Tower at Cologne | 1800 | 12.00 | 24.00 | .25 | 56.00 | 5.00 | 2.75 |

The hardening of hydraulic mortars has often been the subject of investigation, and is generally considered under two heads; first the mere setting, the congealing of the mass from a fluid state to a moderate degree of hardness; and secondly, their hardening to a stony state. The cements when thus considered are divided into two classes. The first, of which the Roman cement is the type, embraces the mixture of caustic lime with pozzuolana, pulverized tile and brick; and those hydraulic mortars obtained by burning hydraulic lime and marl.

The second class are the Portland cements, these containing no fresh caustic lime.

Collecting the results of all the experiments on the Roman cement, the conclusion is that the setting is due to the combination of acid silicates or silica, with burnt lime, forming a hydrated silicate of lime, intermixed with the alumina and oxide of iron.

The hardening of Portland cements, which is effected by the mixture with water, consists in the hydration of the calcium and aluminum silicates which exist ready formed but anhydrous, in the cement.

Concrete or beton. These terms, by no means originally the same, have become almost strictly so by usage. As generally understood in modern practice, they apply to any mixture of mortar (generally hydraulic) with coarse material, such as gravel, pebbles, shells, or fragments of brick, tile, or stone. More strictly speaking, as originally accepted, the matrix or gangue of the beton possesses hydraulic energy, while that of the concrete does not. Concrete is daily growing into more extensive use and application, for it can be used in almost every combination of circumstances known in practice. It is superior to brick work in strength, durability, and economy, and in some cases is considered a reliable substitute for the best stone.

For submarine masonry concrete possesses the advantage that it may be laid without exhausting the water.

The size of the broken stone for concrete is generally specified not to exceed 2 inches on any edge, but all sizes up to 4 or 5 inches may be used, care being taken that the other ingredients completely fill the voids. The stone is either broken by hand, or by machinery ; and of the latter Blake's Stone Crusher is generally used. It will break from 6 to 7 cubic feet per hour.

The cement used should be slow setting, especially when the concrete is to be rammed.

The mixing of the concrete is effected by hand and by machinery ; if done by hand, the gravel and pebbles are first separated by screening, into different sizes, the concrete is then prepared by spreading out the gravel on a platform of rough boards, in a layer from 8 to 12 inches thick, the smaller pebbles at the bottom and the larger at the top. The mortar is then spread over the gravel as uniformly as possible; the whole is then thoroughly mixed, two turnings sufficing.

The concrete for the New York City docks consisted of 1 part of either English, or Saylor's American cement, 2 of sand, and 5 of broken stone.

That made of English Portland after drying a few days, and then being immersed for six weeks, required about 30 tons per square foot to crush it.

That used in the foundations of the Washington Monument at

Washington, was, English Portland 1 ; sand 2 ; gravel 3 ; and broken stone 4 ; this stood a crushing strength of 155 tons per square foot when 7½ months old.

Some of the concrete of Rosendale cement 1 ; sand 2 ; and broken stone 6 ; had become so hard at the end of a year that to remove some of it they had to drill and blast it.

The strength of concrete is affected by the quality of the broken stone, as well as by that of the cement, the degree of ramming, etc., and at the end of 1 year concrete should stand a crushing strength of 100 tons per square foot. Concrete is used for bringing up an uneven foundation to a level before starting the masonry. It may readily be deposited under water in the usual way of lowering it, soon after it is mixed, in a V shaped box of wood or plate iron, with a lid that may be closed when the box descends.

The consistency and strength of the concrete would of course be impaired by falling through the water from the box, and moreover it cannot be rammed under water without further injury. Still, if good, it will in due time become sufficiently strong for engineering purposes. Concrete in this way has been deposited a distance of 50 feet. The area upon which it is deposited must previously be surrounded by some kind of enclosure, to prevent the concrete from spreading beyond its proper limits, and to serve as a mould to give it its proper shape. This will usually be a close crib of timber or plate iron, without a bottom, and will remain after the work is done.

The concrete should extend out from 2 to 5 ft. beyond the base of the masonry and the soft mud should be removed before depositing the concrete. It has been used in very large masses ; as in the foundation of a graving dock at Toulon, France ; where it was deposited to a thickness of 15 feet over an area of 400 ft. by 100 ft., forming as it were, a single artificial stone of that size.

When concrete is deposited under water, especially in the sea. a pulpy, gelatinous fluid is washed from the cement, and rises to the surface. This causes the water to assume a milky hue, hence the term " Laitance," applied by French Engineers. When this precipitate forms on the cement it prevents it from setting properly, thus lessening the strength of the mass. It is usually removed from the enclosed space by pumps, and is supposed to be caused by the magnesia contained in the water.

The weight of good concrete is 130 to 160 lbs. per cubic foot dry, and it costs from $5 to $9 per cubic yard if roughly deposited, and from $9 to $15 if first made into blocks, depending on locality, size of blocks and quality of cement used.

A. L. McCulloch.

# RAILWAY SURVEYS.

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A SHORT DESCRIPTION OF THE WAY IN WHICH THE WORK IS DONE IN THE FIELD.

*Mr. President and Gentlemen :*

The object the writer has in view in this paper, is the presentation of the subject of railway location in a concise form, so as to give Engineers who have had no experience in this branch of the profession, an idea of how the work is actually done in the "field."

The subject then will not be taken up at the conception of the scheme ; but at the time when the location Engineer receives instructions to locate the road.

These instructions will include a description of the general routes ; a list of the places to be touched by the line ; the maximum limit for curves, and for grades, and other instructions of a similar nature.

The first thing to be done is to examine the ground carefully. This is done by the Engineer in charge, who usually walks over the ground examining the different *possible* routes,—comparing one with another. Usually some of the routes have some very evident disadvantages when compared with the others, so that they can be abandoned ; thereby saving the expense of running a line over them.

The work is now ready for the "party" to commence the "preliminary line."

Before describing the "preliminary line work," it may be well to say a few words about the "party."

The party, as it is generally organized, comprises—The Engineer in charge ; the transit-man ; two chainmen ; one forepicket-man ; one back picket-man ; an axeman for making "Station-stakes," "Hubs," and "Hub-stakes,"—and from two to five or six axemen (depending on the nature of the country) to chop out the line. This completes the "transit party." Next is the levelling party—composed of a leveller, a rod-man, and an axeman—where sections are taken by the leveller ; but when there is a topographer along with the party, he has this last axeman to assist in measurements, etc., required in taking sections.

The Preliminary Survey is now commenced. The Engineer in charge being acquainted with the ground, knows approximately where the 'location line" will be. His object is, then, to get the preliminary line as near as possible to this place. To accomplish this, he directs the transit-man in what ever way may be necessary. If the country is flat, a general bearing is given; if it is undulating, and not covered with bush, the line is run from point to point, as they appear, or if the country is both rough and covered with bush, the Engineer in charge stays right ahead of the transit party giving directions as he sees fit. On side-hill work, and where it is evident that nearly a maximum grade will have to be used, the position of the preliminary line is determined by knowing the elevations of the stations, and allowing for the change in elevation due to grade. In this way it can easily be determined whether the preliminary line is above or below, where the location will be—by the grade assumed. These elevations are given by the levelling party, keeping close to the transit party.

Stakes are set on these lines one hundred feet apart, each hundred feet being called a "station," and on each stake is written the number of the station it belongs to. At angles, and wherever else necessary, "hubs" are driven and centered with tacks. "Hub-stakes" are placed a couple of feet to the left of the "hubs." On each "hub-stake" is marked the "plus" to the hub—and the number of the station stake, immediately preceding it. The chainage is continuous.

Closely following the transit party is the levelling party, taking the elevation of every station, and of as many "plusses," as are necessary to give a correct profile; and a few B.M.'s are also established to check the location levels.

Next comes the topographer, who with a hand level takes cross-sections, both to the right and to the left, as close together as is necessary to give every change in the ground, and long enough to include the limits of the proposed location line. After the ground has been gone over in this way, the next step is to plot the work.

The alignment is plotted on some convenient scale for working from. The closeness of the contours and the nature of the work determine the scale, frequently it is as large as $100' = 1''$, and varies to $400' = 1''$.

The levels are plotted on profile paper, and the cross-sections, on cross-section paper.

The next step is to put the contour lines that come within the limits of the cross-section, on the plan. Given for example that the contours are to be traced for each even five feet of elevation from datum.

Look along the ground line of the plotted cross-section and note where it intersects with the horizontal line on the cross-section paper, indicating the elevation of the contour under consideration; find the distance this point is from the centre line (from which the section was taken) and plot its position on the plan. Do this for as many sections as are intersected by the given contour. Now draw a line through these points, and this line will be the contour required. In a similar way the other contour lines are determined and plotted.

The next step is to place the location line on the plan.

The plan, with the preliminary alignment and the contours, now presents very plainly all the information taken in the preliminary survey, making the work of placing the location line comparatively easy.

Usually there are points which determine the position of the "location line" at certain places, such as river crossings, prominent bluffs, etc.

Now let us consider the location of the line between two of such points.

By examining the contours on the plan, and scaling the distance between the points, the minimum grade can be found.

Then, if possible, "sustaining ground" is found for this minimum-grade line; that is the line is so adjusted (on the plan), and such curves introduced that will make the ground line coincide as nearly as possible with the grade line as above determined.

This will in most cases introduce too much curvature, and generally on the other hand, by making the line straight, the cost of construction would be too great. To find a proper mean between these two extremes, is the problem that presents itself to every location Engineer.

The cost of operation of the road is increased by the curves and the grades. Experiments have been made to determine the resistance due to each kind of curvature, (*i.e.* 1° curve—2° etc.), and also due to grades.

This resistance requires the expenditure of more power to overcome it, therefore more expense. Also, there is more wear and tear on a curve than on a straight line. By determining this increase in cost of operation for a prospective traffic for one year, and by considering this amount as interest on a certain principal, the location Engineer knows how much more cutting or filling he can take (at a certain price per cub. yd.) in making improvements in alignment or in grades, and still have the saving in cost of operation equal to the interest on the increased cost of construction. In this way he determines the amount of curvature that it is wise to introduce. A trial location line is placed on the plan with the curves traced in; the stations are called off, then the elevations of the stations are taken from the contour lines, and a profile plotted. Then the grade lines are put on the profile, showing the amount of "cut" and "fill."

The effect of any change in lessening the curvature, or easing the grades by changing the location, is now considered, and an estimate made of the cost of the road (if required to compare with another proposed location or for any other reason). Some of the advantages of the system of location by contours are very apparent from the foregoing; for a very close estimate can be made for any location line within the limits of the cross sections in the above way. The profiles made from the plan and contours compare very closely indeed with the one made from the level notes taken after the line has been finally run in.

After a line has been decided on from the notes on the plan, all that remains to be done is to trace it out on the ground.

Notes are taken from the plan showing the relative position of the location line compared with the plotted preliminary line ; and then by using these notes, and the preliminary line on the ground, the location line is easily established. Then the levels are taken—" bench marks " established—plans and profiles plotted—and the work of location is finished.

A. R. Raymer.

# PETROLEUM.

*Mr. President and Gentlemen :*

This is essentially the age of progress. The arts and sciences have made wonderful advancement within the present century. Many newly discovered, or at least recently developed agencies, have been at work revolutionizing the old methods of manufacture, and rendering new and improved methods possible.

Among the foremost of these agencies is Petroleum, which within the last thirty years has brought cheerfulness and comfort into millions of homes throughout the world.

The name Petroleum, is a combination of two Latin words "petra" a rock and "oleum" oil, thus showing its source and character. The oil is not found everywhere on the globe, but seems to be confined to certain localities, the principal of which are in western Pennsylvania, and at Baku, Russia.

From wells in Sicily and in Burmah, the ancients used to obtain an oil which they burned in their lamps ; but it is only recently that the trade has been fully developed. The oil is generally found by boring in beds of sand-stone at a great depth, where the oil, often accompanied by an inflammable gas, is under a pressure so great as to force it up through the bored hole, throwing the boring tools high into the air.

Generally where we find oil, strata of coal are also found, only at a higher level. Very often, as in Pennsylvania, the oil bearing strata have a decided dip in the same general direction.

Among many theories as to the origin of petroleum, the two following seemed to be the best supported by known facts :

1st. The oil has been formed by distillation from bituminous coal by the action of great heat and pressure. In support of this theory is the fact that crude Petroleum can be made by distilling coal in iron vessels made for the purpose ; and indeed this was done to a considerable extent before the great oil fields were discovered a few years ago ; hence, the name "coal oil," was first given to the product. This theory would make it appear that the oil was formed in the strata of coal, and from them found its way to the strata of sandstone, or occasionally limestone, which, owing to their porous nature, caught and held the oil.

The second theory supposes that the oil was formed in the same strata in which it is found, by the action of great heat and pressure upon the sea-weeds and animal remains of which the rock was partly composed. The fossil remains found in the rocks, together with the fact (as I understand), that Petroleum can be formed from similar plants and animals to-day, are the arguments in favor of this theory.

Until the middle of this century, oil had been found on the water near springs at Seneca Lake, and at many other places, but in small quantities. In the year 1859, Col. E. L. Drake, tried to reach the oil by boring near Titusville, New York State, and at 70 feet he struck a rich vein from which was taken the first of the many millions of barrels which the great Pennsylvania oil region has supplied. Before a year had passed, 2000 wells are said to have been started, which number by 1885 had increased to 42,500.

The cost of a well is considerable :—$25,000 to $50,000 for the land, and also another $4,000 to $8,000 for the hole alone, besides other expenses, and then no oil may be struck. Previous to the sinking of a well, a tall frame-work derrick is erected upon a strong foundation of hewn logs ; everything must be strong and solid to resist the great strain. The derrick is about 20 ft. square at the bottom, and 4 ft. square at the crown-block, the topmost part. The height is about 80 ft. The whole structure is built up piece by piece, and strongly braced, the corner posts being made of 2 inch hemlock planks spiked together at the edges, trough-shape, with the open part turned inside. Through the centre of the crown-block, a heavy square piece of timber, a hole is cut in which is fitted a small wheel, over which the heavy 2 inch rope used in drilling is run. A ladder is built up one side of the derrick, a floor is laid sloping to two sides from the middle to let water run off. In the centre of this where the well is tobe bored, a hole is left. On one side of the derrick are fixed the bull-wheels, two great wooden wheels on each end of a heavy windlass, upon which is wound the drill cable.

Upon a heavy post firmly braced, the walking-beam works. The inside end of which is directly over the hole in the centre, while the other end is connected by a pitman with a crank attached to the drive-wheel. This is connected with the engine by a belt, and with the bull-wheel by what is called the bull-rope. A small line run through a pulley near the top of the derrick is wound around the sand reel, which may be connected with the drive-wheel by friction gearing.

The drill itself, is made up of several pieces.

The rope-socket, to which the drill cable is made fast, is two or three feet long. Into the lower end of this is screwed the sinker-bar, a round iron or steel bar about 4 inches in diameter, and 12 to 14 feet long. Into the lower end of this go the jars, two strong steel links made to slide within each other like the links of a chain. The jars are about 7 ft. long when closed, and about 2 ft. longer when drawn out. Below these the auger stem, the longest and heaviest part is fastened. It is very much like the sinker-bar, but is from 35 to 40 feet long. Into the lower end of the auger stem is screwed the last piece, the bit. This is the part which cuts and breaks the hole down through the rock. It is 4 ft. long, the same thickness at the upper end as the auger-stem, but broadened and flattened toward the lower end ; about 4 inches thick, and from 4½ to 13 inches wide.

With all pieces screwed together, the drill is 65 to 70 ft. long, as firm and rigid as one piece, and weighs from 3000 to 3,500 lbs.

Besides the drilling tools there are the sand pump, the boiler and the fishing tools.

The machinery, and the lower part of the derrick are generally housed in, as work is to be carried on night and day, winter and summer.

Four men make up an oil-well "crew,"—two drillers, and two tool dressers, but only two (a driller and a tool dresser) work at a time. The day is divided into two "tours," of 12 hours each. From midnight till noon, is the morning tour ; and from noon till midnight, the afternoon tour.

The upper part of the well, say for 80 to 100 feet, is "spudded" down. A wooden conductor, or iron drive pipe is put down through the loose earth, to the first bed of rock. A short heavy spudding-bit is used instead of the long drill. And as the walking-beam cannot be used yet, a jerk-rope is fastened around the cable above the spudding-bit, and the end made fast to the crank, from which the pitman is removed. As each turn of the drive-wheel first tightens then slackens the jerk rope, the spudding-bit is raised and let fall heavily to the bottom of the hole, to cut and break the rock at each blow.

When sufficient depth is drilled in this way, to admit of the use of the long drill in connection with the walking-beam, the spudding is stopped, and the regular drilling commenced. The long drill with its parts screwed very tight together is swung over the hole and lowered into it. Then when all is clear, the brake is thrown off the bull-wheel, and the heavy drill drops down, each moment increasing its speed, until it is near the bottom, when the driller applying the brake slows it up before it strikes bottom. From a great iron hook fastened to the inside end of the walking-beam, hangs the "temper-screw," a heavy screw, four or five feet long, set in a strong steel frame ; while attached to this, below, are the clamps, two iron blocks or jaws hinged together, so that they can be opened and closed. The driller puts the clamps around the cable and screws them up tight so that it cannot slip. He then pulls two or three coils from the bull-wheel, which leaves the cable swinging loose above the clamps.

As soon as the other end of the walking-beam has been fastened to the crank by the pitman, the engine is started by a pull on one of the cords, running to the engine-house. As the inner end of the walking-beam flies up, it raises the drill a couple of feet, and on coming down the heavy drill drops back, cutting, or rather breaking and crushing through the rock.

In this way 40 or 50 blows are given every minute, and as the old proverb says, "constant dropping wears away the rock."

During this work the driller keeps turning the temper-screw above the clamps, thus gradually lowering and turning the drill in the hole, until it has been lowered the length of the screw, or as the driller says "one bit." It is by these "bits" they measure roughly the distance drilled through a certain rock, or during one tour.

The next thing is to get out of the hole the little pieces of rock just cut by the bit.

A pull of the cord stops the engine; the clamps are unfastened; the engine is again started, and the bull-rope from the drive-wheel turns the bull-wheel (which has been thrown into gear), thus winding up the cable and pulling the drill out of the hole. A long iron bucket with a valve, which opens to let in the muddy material at the bottom of the well, is now lowered by a light line called the sand line. When this sand pump, as it is called, is lifted again, the valve at the bottom closes, and the wet material is lifted out.

If the bit is much worn, it is removed from the drill, and a sharp one put in its place, and the whole thing lowered into the hole once more. The long screw is pushed up into the frame again, the clamps are put around the cable, and the drilling is resumed.

The tool dresser now attends to the engine and to sharpening the worn bit.

Water is always kept in the well when drilling is going on, to soften the rock and keep the loose material in a thin muddy state; but sometimes as the hole goes down through the rock, streams of water are tapped, which flood the hole often to overflowing. This greatly interferes with the drilling, as the water tends to bury up the drill and prevent it from striking as hard a blow on the rock as it would otherwise do. A heavy bucket like the sand pump, only much longer, called the bailer, is sometimes used to free the hole from water, but this cannot be done where there is a big flow. In that case it is necessary to put large iron-pipe casings in the well down to a point below where the water comes in, and thus shut it out. The separate pieces are screwed together at the ends as length after length is lowered, and when they are in the well, they form a continuous water-tight iron lining. If water is met with at different levels, smaller casings must be successively lowered inside of those already in place to stop the new leaks as the work goes on. Sometimes three, or rarely four strings of casings are needed in the one well.

One great difficulty in drilling wells is in tools breaking or coming loose while in the well. These parts have to be fished for, and thus a great deal of time and sometimes the well itself is lost; if the broken part cannot be grappled, and the well has to be abandoned, great loss falls upon the unhappy contractor.

In some instances the desperate effort has been made to drill past the broken tools; an effort which has occasionally been crowned with the success it deserved.

If a well has to be abandoned, the casing is first taken up if possible, and the derrick is then torn down and removed to another place. Suppose, however, that all has gone well, and the oil sand is at length reached, the boiler and forge are removed to a safe distance and all night-work is stopped, as there must be no lights burning near the well. Word is sent for the tank builder, and in an astonishingly short time a large tank with a capacity of several hundred barrels is built.

By certain signs the driller can tell about how fast the oil is rising in the well. The drill is drawn out and hastily swung aside. The driller, who has been listening over the hole, suddenly tells all to run back to the engine house, and he himself starts. Then comes the oil bubbling and boiling over the mouth of the well; up it goes, each spurt sending it higher and higher, a great fountain of golden-colored oil flooding everything. Still it rises—half-way up the derrick—a rush and roar up to the top of the derrick and out through it, and away above it, it breaks into drops, the spray falling back a golden shower in the bright sun-light. It soon declines, however, and in a short time the derrick is left dripping while the oil flows in a steady stream out of the ground. A large pipe is quickly run from the mouth of the well to the tank, and all the oil that comes now is saved.

Pipes are laid from a great many surrounding oil wells to the large tanks in the valley, which have a capacity of about 35,000 barrels each. These tanks are generally owned by some transportation company, which sees to the transportation of the oil either by rail or by immense lines of pipes.

Arrived at the refinery, the oil is allowed to stand in great tanks until the water, sand, etc., which have come from the well with it, have settled to the bottom. The oil is then distilled by boiling it in great iron stills.

In this process the vapors arising from the boiling mass, are condensed in the long crooked iron pipe, "the worm," and the distilled liquid is collected, while a thick black substance is left in the bottom of the stills. Sulphuric acid, caustic, soda and other chemicals, are added to the former.

and the distillation repeated several times, until the different products are thoroughly separated.

The principal of these is "kerosene" (coal oil), used so extensively for illuminating purposes. Then there is "gasoline," a fluid used instead of coal in the manufacture of gas for public and private use; generally for the latter.

There is also "naphtha," an exceedingly inflammable gas. This, if mixed with kerosene, causes it to catch fire very easily, and often explode, resulting in great damage.

Another product is rhigolene, an exceedingly light volatile fluid, used sometimes to prevent pain in surgical operations.

Besides these, are mineral sperm oil, several lubricating oils and paraffins.

Lastly, the thick tarry residuum also has its uses.

There are many interesting things connected with Petroleum that might be dwelt upon, such as the natural gas that accompanies it; the subject of blasting wells, and the further treatment of the transportation of the oil, etc., but the time allotted for this paper will not allow of their discussion.

W. J. WITHROW.

# NOTES ON IRON BRIDGE BUILDING.

*Mr. President and Gentlemen :—*

Though the limits of the present paper will not allow the writer to enter fully into the details of this important branch of engineering, he yet hopes that he may give some insight into the method adopted in bridge works in carrying on their operations.

Iron bridge building is properly classed under mechanical engineering. Besides designing bridges, viaducts, roofs and floors for buildings, etc., the bridge engineer must be able to plan the works, including machinery, which may be required for the making of any extraordinary piece of work.

Economy of construction in the shop, and facility of erection in the field, are the two most important considerations to be kept in view in getting up the plans for a structure. Of two bridges built to suit the same strains, one may be very much cheaper than the other, the difference being due to the style of the bridge and to the manner of making joints and connections. From practical considerations, bridge engineers have almost unanimously concluded that the most economical designs for various lengths, for R.R. bridges, are as under.

Spans up to 16 feet........................Rolled beams.
" 16 to 60 " ..................Rivetted plate girders.
" 60 to 90 " ..............Rivetted lattice girders.
" over 90 " ..................Pin connected trusses.

Let us suppose, now, that a R. R. Company or some corporation require a bridge. Their engineer communicates with various bridge companies, sending them a copy of their specifications and the length of the span, asking for tenders accompanied by general plans and strain diagrams. These plans are examined by the R. R company's consulting engineer, and the contract awarded according to his decision.

Very often the tender is for a lump sum, but sometimes at so much per pound. The latter is the better, since it does not create a tendency on the part of the contractors to " skin " the work.

Working drawings for the shop must now be made. These are generally drawn to a scale of $1\frac{1}{2}$ or 1 inch to the foot, or sometimes even full size for joints. Though they are drawn to scale, every dimension must be figured on the drawing, and repetition is by no means a fault. In some offices the drawings are made on white paper, and then traced so as to be capable of reproduction by blue printing; in others they are made directly on the tracing linen, on the unglazed side, a stout variety of which is made expressly for the purpose. Construction lines are drawn in with red ink, all others with India ink, and should be firm and black, no shade lines being used. Red ink takes very faintly on the blue print. The tracing is placed on file in the office, and the blue print sent to the shop.

It first goes into the template maker's hands who reproduces the structure exactly in wood, though the different pieces are not fastened together, but are made so as to be used in marking off the metal.

Wherever a rivet is to go a $\frac{3}{4}''$ hole is bored in template. In marking off the iron, these templates are simply clamped to the metal, the punch inserted into each hole where it is made to fit exactly, and slightly tapped with a hammer. A little mark is left which serves as a perfect guide in punching the holes.

When all the pieces are punched and cut to the right lengths, they are assembled together with bolts of sufficient number to hold them, and then brought to the rivetting machine. Machine driven rivets are always preferable to hand driven, and for this reason all rivets should be spaced far enough away from the backs of L's, T's, etc., to allow the jaws of the rivetter sufficient room.

After the work is all rivetted up, it is cleaned of scales, rust, etc., with a stiff brush, and then given first a coat of linseed oil, and next one of brown iron ochre paint. The different pieces are then marked so that when they are brought to the field they may be readily picked out.

The buyers generally send a man to inspect the work as it is being made. He must see that the rivets are well driven (sometimes they are quite loose and with imperfect heads, due to the jaws of the rivetter not being kept in good repair), that the pieces are of the dimensions called for in the drawings, and of the right length so as to cause no undue straining in the field, when the structure is being erected; that they are well and truly made, without warps, bends, etc., and that the iron used comes up to the requirements of the specifications. The following are among the chief requisites for good bridge iron, taken from Theodore Cooper's specifications for iron bridges :—

All wrought iron should be tough, fibrous and uniform in character, and should have a limit of elasticity of at least 26,000 lbs per square inch.

Finished bars must be thoroughly welded during the rolling, and be free from injurious seams, blisters, buckles, cinder spots, or imperfect edges.

For all tension members the bars should stand the following tests :

Full sized pieces, flat, round or square, not over $4\frac{1}{2}$ sq. in. sectional area, should have an ultimate strength of 48,000 lbs. per sq. in., and stretch

12½ per cent. Bars greater than 4½ sq. in. sectional area, when tested in the usual way, will be allowed a reduction of 1,000 lbs. per sq. in. for each additional square inch of section down to a minimum of 46,000 lbs. per sq. in.

When tested in specimens of uniform sectional area of at least ½ sq. in. for a distance of 10″, taken from the tension members which have been rolled to a section not more than 4½ sq. in., the iron should not break at less than 50,000 per. sq. in., and stretch 18 per cent. in 8″. Specimens taken from bars of a larger cross section than 4½ sq. in. will be allowed a reduction of 500 pounds for each additional square inch of section, down to a minimum of 48,000 lbs.

The same sized specimens taken from angle and other shaped iron shall have an ultimate strength of 48,000 lbs. per sq. in., and elongate 15 per cent. in 8″.

The same sized specimens taken from plates less than 24 inches in width, shall have an ultimate strength of 48,000 lbs. per sq. in., and elongate 15 per cent. in 8″.

The same sized specimens taken from plates exceeding 24 inches in width, shall have an ultimate strength of 46,000 lbs. per sq. in., and elongate 10 per cent. in 8″.

All iron for tension members must bend cold, for about 90°, to a curve whose diameter is not over twice the thickness of the piece, without cracking. At least one sample in three must bend 180° to this curve without cracking.

When nicked on one side and bent by a blow from a sledge, the fracture must be nearly all fibrous, showing but few crystalline specks

Specimens from angle, plate and shaped iron, must stand bending cold through 90°, and to a curve whose diameter is not over three times its thickness without cracking. When nicked or bent its fracture must be mostly fibrous.

Rivets shall be made from the best double refined iron.

Of late years steel has been considerably used in bridges. At present, however, the opinion of leading professional men is averse to using it altogether in place of iron, preferring the less strong but better known metal for the tension members, or those subjected to alternating stress, and using steel only in compression members and in webs of plate girders.

Steel may vary very much in character, and different specifications call for different standards. Below is given the specification for steel for the Harlem River bridge.

1. The steel shall be uniform in character for each specified kind. The plates, finished bars, and shapes must be free from cracks on the faces or corners, and have clean smooth surfaces.

2. All steel for the arch ribs, girders and tension rods, shall have an ultimate strength of 62,000 or 70,000 lbs. per sq. in., with an elastic limit of not less than 32,000 lbs. per sq. in., and a minimum elongation of 18 per cent., when measured on an original length of 8 inches.

3. All steel for rivets shall have an ultimate strength per sq. in. of 56,000 to 64,000 lbs., with a minimum elongation of 25 per cent.

4. Tests shall be made by samples cut from the finished material after rolling. The samples to be at least 12 inches long, and to have a uniform sectional area of not less than $\frac{1}{2}$ sq. in. All the samples must shew uniform, fine-grained fractures of a blue steel-grey color, entirely free from fiery lustre, or a blackish cast.

5. Samples cut from finished materials for the arched ribs, girders, or tension members, tested before or after heating to a low cherry red, and cooled in water at 82° Fah. must stand bending to a curve, whose inner radius is $1\frac{1}{2}$ times the thickness of the sample, without cracking. Samples of rivet steel, before and after being heated to a light-yellow heat, and quenched in cold water, must stand closing solidly together without sign of fracture. To check the uniformity of the material, the manufacturer of the ingots shall cause to be made from each cast sample bars of $\frac{3}{4}$ in. round, with a definite and uniform reduction equivalent to reducing a 4″ ingot to the sample size. They shall mark the same in a manner to identify the final product.

6. The usual chemical tests shall be furnished in connection with these samples.

7. No work must be put upon any steel at or near the blue temperature, or between that of boiling water and the ignition of hard-wood sawdust.

8. Any steel straightened or worked cold by use of the hammer or gag press, must be afterwards wholly unnealed.

Below are given the results of some tests made on 50,000 lb testing machine of the Passaic Rolling Mill Co., and also one made on full sized Eye-bar, on Fairbanks large 200,000 lb. machine.

E. W. Stern.

## WROUGHT IRON.

| TESTED FOR. | Date. | SPECIMEN. | Mark. | Size Inches. | Area in Square Inches. | Broke at Pounds. | Strain per Sq. Inch in Pounds. | Limit of Elasticity in Pounds. | Limit of Elasticity per Sq. Inch in Pounds. | Elongation in 8 Inches. | Elongation Per cent. of Length. | Area of Reduced Section in Sq. In. | Per cent. of Reduction. | Test Made by | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Jan. 3rd | $\angle 5 \times 3\frac{1}{2} \times \frac{9}{16}$ . . . | 1 | 0.994<br>.585 | .5815 | 29000 | 49870 | 16000 | 27500 | 1.60 | 20 | .449 | 22.7 | McKee.. | All fibrous |
|  | " " | 9″ [Web. . . . . . | 2 | .315<br>1.003 | .3160 | 16000 | 50630 | 9800 | 30800 | 1.95 | 24⅜ | .213 | 32.5 | " | " |
|  | " " | 15″ [Flange. . . . | 3 | .580<br>.997 | .5782 | 30200 | 51430 | 17000 | 29400 | 1.60 | 20 | .367 | 36.0 | " | " |
|  | " " | 15 [Web. . . . . . | 4 | .540<br>1.000 | .5400 | 27000 | 50000 | 16000 | 29500 | 2.10 | 26¼ | .337 | 37.0 | " | " |
|  | " " | 10½″ [Flange . . | 5 | .342<br>.995 | .3403 | 17800 | 52400 | 11000 | 32320 | 1.60 | 20 | .267 | 22.0 | " | " |

## MILD STEEL.

| TESTED FOR. | Date. | SPECIMEN. | Mark. | Size Inches. | Area in Square Inches. | Broke at Pounds. | Strain per Sq. Inch in Pounds. | Limit of Elasticity in Pounds. | Limit of Elasticity per Sq. Inch in Pounds. | Elongation in 2 Inches. | Elongation Per cent. of Length. | Area of Reduced Section in Sq. In. | Per cent. of Reduction. | Test Made by | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Jan. 16th | Boiler Plate. . . | 37 | .496<br>.996 | .494 | 29550 | 59800 | 18600 | 37600 | .78 | 39 | .212 | 57 | St. J. C. |  |
|  | " " | " " | 38 | .483<br>.993 | .480 | 28700 | 59800 | 17900 | 37300 | .80 | 40 | .222 | 54 | " |  |
|  | " " | " " | 39 | .502<br>.996 | .500 | 28800 | 57600 | 17800 | 35600 | .80 | 40 | .206 | 59 | " |  |
|  | " " | " " | 40 | .491<br>.996 | .489 | 28700 | 58700 | 18100 | 37000 | .83 | 41½ | .201 | 59 | " |  |
|  | " " | " " | 41 | .499<br>.995 | .497 | 29550 | 59500 | 18100 | 36400 | .81 | 40½ | .220 | 56 | " |  |
|  |  |  | 42 | .495<br>.996 | .493 | 28950 | 58700 | 18000 | 36500 | .87 | 43½ | .196 | 60 | " |  |

## REPORT OF TESTS MADE ON FULL SIZED SPECIMENS.

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| | | | | |
|---|---|---|---|---|
| | | Material | Wrought Iron. | |
| | | Mark | A. | |
| | | Test No. | 3872 | |
| | | Shape Original | Eye-Bar. | |
| | | Shape of Test piece | Full Size. | |
| Dimensions. | Original. | Length in feet | 17.13 | Under Gauge 15 ft. |
| | | Dimensions in ins. | 3.990 | |
| | | Thickness in ins. | .873 | |
| | | Area in sq. ins | 3.483 | |
| | Final. | Length in feet | 16.81 | |
| | | Dimensions in ins | 3.345 | |
| | | Thickness in ins | .625 | |
| | | Area in sq. ins | 2.091 | |
| | | Per cent. Elongation | 12.07 | |
| | | Per cent. Reduction | 39.97 | |
| Stress in lbs. Tension. | On Spec. | Elastic Limit | 96000 | |
| | | Maximum | 159680 | |
| | Per sq. in. | Elastic Limit | 27562 | |
| | | Maximum | 45846 | |
| | | Fracture | Fibrous. | |

### REMARKS.

Pin holes 3.50A, 4.90B. Sides of eyes 3.34A, 3.405A, 2.990B, 3.065B. Backs of eyes 3.525A, 3.205B. Elongation .18A, .34B. Thickness of metal around eyes .855, .923. Bar broke in body 19½″ from B end.

# ANGLE BLOCKS.

*Mr. President and Gentlemen,—*

The shape of the angle blocks and the length of the braces for a Howe truss may be determined either graphically or analytically. The first method appears to the writer to be by far the most useful, being the quickest and least liable to error. The method used on the C. P. R., as seen in Fig. 2, was as follows :—

First plot the panel, AD being the distance between the upper and lower chords, and AB the distance between the centres of the vertical rods. The larger the scale of this panel the better. One foot to the inch answers well. Then cut two right angled set squares "E"—paper does well—and graduate them by the assumed scale. Now, if the width of the brace is, as in this case, twelve inches, all that is necessary is to place the two set squares closely against the T square and shift until the zero mark and twelve inch mark of both set squares are in contact with the edges of the panel. We have now got the position and length of the longest brace of the given breadth that can be inserted in the parallelogram ABCD, and we have merely to scale off the length of the brace and the size of the angle block necessary to support it. These last dimensions should be noted on a rough sketch (as G) for future reference.

It is often required that all of the braces of a Howe Truss shall be of the same length, but as the braces are not all of the same width there is some doubt as to the size of the angle blocks, which must all be of the same height and have the same inclination towards their base. For instance, suppose we find the angle block for the widest brace, then for narrower braces the blocks are merely cut off, but some engineers object to this plan because the brace does not touch the chords and consequently is more liable to slip. Others go to the opposite extreme and design the block for the narrowest brace and let the wider braces butt against the chords. A course intermediate between these two is probably the best.

Of the analytical solutions, none that I have seen appear worthy of replacing the graphical method. I will, however, indicate the simplest method that I have come across, lest some of you should waste your office hours, as I did, in trying to find a simple solution, when old engineers say there is none.

Prof. P. H. Philbrick published the following solution in the May number of *Van Nostrands* in 1881 :—

Let ABCD Fig. 3 be the shape of the panel and FGNM be the brace, the length of which is required.

Let $a = \frac{1}{2}$ width of panel given.
$b = \frac{1}{2}$ length of panel given.
$\alpha =$ angle BOE given.
$FG = 2c =$ breadth of brace given.
$b = \frac{1}{2}$ length of brace required.
$\gamma =$ angle HOE = angle BFG required.

$$\sin^2\gamma + \cos^2\gamma = 1 \qquad (1)$$

$$\frac{\cos\gamma}{\sin\gamma} = \frac{b - c\sin\gamma}{a - c\cos\gamma} \qquad (2)$$

Now by putting $\alpha$ for $\gamma$ in (2) and combining with (1) he gets

$$\cos\gamma = \frac{b - c\sin\alpha}{\sqrt{(a - c\cos\alpha)^2 + (b - c\sin\alpha)^2}}$$

and

$$\sin\gamma = \frac{a - c\cos\alpha}{\sqrt{(a - c\cos\alpha)^2 + (b - c\sin\alpha)^2}}$$

which results are sufficiently accurate.

Having now ascertained the sine and cosine of $\gamma =$ angle HOE = angle BFG, it is easy enough to find FG and BG.

For $FB = 2\ c\cos\gamma$
and $BG = 2\ c\sin\gamma$.

Prof. Philbrick has the following rather long equation for finding the length of the brace or $2l = \sqrt{(a - c\cos\gamma)^2 + (b - c\sin\gamma)^2}$

It seems to me that it would be easier to find $2l$ as follows: It may be seen in Fig. 3 that $FD = \frac{EF}{\sin\gamma}$; that $\frac{c}{x} = \tan\gamma \quad \therefore \quad x = \frac{c}{\tan\gamma}$; and also that $EF = ER - FR = a - 2\ c\cos\gamma$.

$$\text{Now } l = FD + x = \frac{EF}{\sin\gamma} + \frac{c}{\tan\gamma}.$$

$$= \frac{a - 2\ c\cos\gamma}{\sin\gamma} + \frac{c}{\tan\gamma}.$$

$$= \frac{a - 2\ c\cos\gamma + c\cos\gamma}{\sin\gamma}$$

$$= \frac{a - c\cos\gamma}{\sin\gamma}.$$

$$= (a - c\cos\gamma)\operatorname{cosec}\gamma = (a - \frac{FB}{2})\operatorname{cosec}\gamma.$$

$$\text{and } \therefore 2l = (2a - FB)\operatorname{cosec}\gamma.$$

It is easy enough to see that it would be far more troublesome to figure out the values for $\cos\gamma$ and $\sin\gamma$, than it would be to go through the whole graphical process, and would be much harder to check. The easiest check on the graphical method is to find the shape of the block at both ends of the brace at the same time and if these agree the work is correct.

T. K. Thomson.

# TRANSITION CURVES.

*Mr. President and Gentlemen,—*

A Railway Curve, as generally laid out, consists of a curve of uniform curvature connecting two tangents. Where the curvature is slight and speed of trains low, this arrangement does fairly well, but, under different conditions, is very defective. Let us consider the case where a train is approaching a 4° curve at a speed of 40 miles per hour. The engine on reaching the curve presses heavily against the outer rail (unless prevented by some means), tending to spread the track and mount the rail. To counteract this tendency, it is necessary to give the outer rail an elevation of about 4 inches for the gauge of 4′ 8½″. In order, however, to give this elevation at the B. C. it is necessary to begin the elevation on the tangent, some distance back from the B. C. With this arrangement then, either the portion of tangent near the curve, or the portion of curve near the tangent is subject to undue strains since trains in either direction, must press either against outer or inner rail.

These defects may, however, be avoided by the introduction of a curve leaving the tangent some distance back from circular curve, with slight curvature, which gradually increases until at the point of junction with the circular curve it is approximately the same, the elevation of the outer rail being kept proportional to the curvature.

All such curves are known as "transition curves," and may be divided into two classes, trackmen's curves and calculated curves.

Trackmen's Curves join points each way from ordinary B. C., keeping within the points set by the Engineer, viz. :—centres on the tangent and circle, and are always lined by eye by the trackmen.

There is one defect common to all curves of this class, which is the unavoidable sharpening of the curve at its junction with the circle, and there may also be other errors due to wrong judgment on the part of trackmen.

Calculated curves are of two kinds, parabolic and multiform, compound or spiral.

A Parabolic Transition Curve is an arc of a parabola joining a tangent and a circle, having the end with the least curvature joining the tangent, and the end with the greatest curvature joining the circle with a common tangent, and approximately the same curvature at point of junction.

This curve although theoretically the better one, is seldom used as it does not admit of ready calculation in the field.

The Multiform Compound Curve consists of a number of arcs of circles of equal lengths but increasing degrees of curvature, each pair of arcs having a common tangent at their point of junction. The arc of least curvature joining the tangent and the arc of greatest curvature of approximately the same degree as the circle, and having a common tangent with it at the point of junction. Evidently the best way to regulate these successive changes of curvature from tangent, or 0° curvature, up to the full curvature of circle is to make them all the same. If this difference is made 10 minutes, then the degree of curvature of the first arc will be $0 + 10' = 10'$; that of the second, $10' + 10' = 20'$; that of the third $20' + 10' = 30'$, etc. Now suppose the degree of circular curve decided on to be $1^\circ = 60'$, then evidently the sixth arc will have the same curvature as the circle and will coincide with it. The number of arcs in the transition curve is, therefore, five, similarly with a 2° curve, the twelfth arc would coincide with the circle, and the number of arcs in the transition curve would be 11; and, generally, if $m =$ degree of circle, $n$ the degree of first arc in the transition curve, and $t$ the number of arcs, then $\frac{m}{n} - 1 = t$.

From this it will be seen that the degree of curvature of the $t+1$ arc determines the number of arcs in the transition curve. With curves of uneven degree, the $t+1$ arc should fall within, or very close to, the circle.

Thus far the curve has been treated as a multiform compound curve, and if one or more points on each arc, in addition to the compounding points be fixed, the curve must so remain. If, however, the only points fixed are the compounding points, then the curve may very easily be made to assume another and much better form.

This form is shewn in Fig. 4, where T'T = tangent; S = beginning of curve; 1, 2, 3 = compounding points; A = compound curve; B = other curve; D = degree of first arc.

The curve instead of starting from the point S with a curvature D, may start from S with less curvature, and gradually increase until it passes through 1 with curvature intermediate between D + 2D; thence without abrupt change, but continuously increasing and passing through 2 with a curvature intermediate between 2D + 3D, &c., &c., these forming a true spiral.

As the track practically assumes this shape when lined by trackmen to centres given as above mentioned, the term "railroad spiral" applied to this curve by some Engineers is quite proper.

It must be kept in mind, however, that the spiral itself is not calculated, but that the calculated curve is a multiform compound curve, through the compounding points of which the spiral is constructed.

The proper elevation of outer rail for any degree of curvature depends on the gauge and speed of trains, and for any other degree (on the same line) the elevation varies directly as the degree. The use of the spiral admits of this condition being fulfilled at all points of curve, as the track may be level on the tangent for its full length, and also the circle may have proper elevation for the full length, without any misproportion in any part of the curve.

The ordinary method of running compound curves is evidently unsuited to the running of a spiral, as it necessitates the setting up of the instrument at each compounding point. It is desirable, however, to adhere to the method of deflection angles and chord measurement, with as few changes of position of the instrument as the nature of the ground will permit. In order, however, to use this method, it will be necessary to calculate special deflection angles for each point.

For purposes of calculation, let us assume the chord length to be 100′, and for the central angle subtending the first chord we will adopt the angle used in practice, viz., 10′. To find the inclination of chords to the primary tangent, suppose the chords on which the spiral is be constructed to be laid down as in Fig. 5.

Let T′T = tangent ; S = beginning of spiral ; S 1 ; 1 2 ; 2 3. = chords ; $S_1$ $S_2$ $S_3$ = central angles ; S = central angle of spiral = sum of $S_1$ $S_2$ $S_3$. Inclination of S 1 to T T $= TS1 = \frac{1}{2}S_1 = 5'$.

To find the inclination of 2 1, draw through 1 the auxiliary tangent a1b and produce 2 1 to intersect T′T in A. Now the inclination of 2 1 = $TA2 = TS1 + A1S = \frac{1}{2}S_1 + S1a + A1a = \frac{1}{2}S_1 + \frac{1}{2}S_1 + \frac{1}{2}S_2 = S_1 + \frac{1}{2}S_2 = 20'$, similarly by drawing the auxiliary tangent cd, and producing 3 2 to intersect T′T in B, we have the inclination of 3 2 $= TB3 = TA2 + A2B = S_1 + \frac{1}{2}S_2 + A2C + C2B = S_1 + \frac{1}{2}S_2 + \frac{1}{2}S_2 + \frac{1}{2}S_3 = S_1 + S_2 + \frac{1}{2}S_3 = 45'$. And generally, the inclination of any chord to the primary tangent, is equal to the sum of the central angles, subtending all the previous chords plus, ½ the central angle subtending that chord.

| INCLINATION. | | | CO-ORDINATES. | | | | DEFLECTIONS. |
|---|---|---|---|---|---|---|---|
| POINT. | CHORD. | i= INCLINATION. | 100 SIN I | 100 COS I | x | y | DEFLECTURE ANGLES INSTRUMENT AT S. |
| S | | 0· 0· | | | | | 0· 00′ 00″ |
| 1 | S.1 | 5′ | .145 | 100. | .145 | 100. | 05′ 00″ |
| 2 | 1.2 | 20′ | .582 | 99.998 | .727 | 199.998 | 12′ 30″ |
| 3 | 2.3 | 45′ | 1.309 | 99.991 | 2.036 | 299.989 | 23′ 20″ |
| 4 | 3.4 | 1· 20′ | 2.327 | 99.979 | 4.363 | 399.968 | 37′ 30″ |
| &c. | | | | | | | &c. |

The inclinations just found are given in the above table under the heading " inclinations."

To find the co-ordinates of extremities of chords. In Fig. 6 let T′T = tangent; a, b, c = chords; 1, 2, 3 = chord extremities; A B = perpendicular to T′T through 3.

Project a b and c on T′T and on A B.

Then evidently $a' = a$ cos inclination.
$b' = b$ " "
$c' = c$ " "
Also $a'' = a$ sin "
$b'' = b$ " "
$c'' = c$ " "
Now $SA = a' + b' + c'$.
And $A3 = a'' + b'' + c''$.

or, in words, the sum of the projections of all chords between any chord extremity and S, is equal to the co-ordinate of that point, when S is the origin of co-ordinates.

In the above diagram with S as origin of co-ordinates, let the distances on ST be y, and distances perpendicular to ST be x. The numerical values of x and y for given points will be found in above table under head "co-ordinates."

To find deflection angles at S. By referring to the last diagram it will be seen that $d_1$, which is the deflection for the point 1, is the angle 1SA, the tangent of which is $\frac{a''}{a'}$ or $\tan d_1 = \frac{a''}{a'}$. Similarly by joining S2 and S3 $\tan d_2 = \frac{a'' + b''}{a' + b'}$ and $\tan d_3 = \frac{a'' + b'' + c''}{a' + b' + c'}$; and, generally $\tan d = \frac{x}{y}$.

The numerical values corresponding to values of x and y previously found for these points are given in the table above, under heading "deflections."

It may sometimes be necessary, owing to obstacles on the ground, to run part of the spiral from S, and the remainder from some other point. To do so it is necessary to find the auxiliary tangent at that point. It is also necessary, in every case, to find the auxiliary tangent at the point where the spiral joins the circle, in order that the circle may be properly located.

Suppose that it is required to find the auxiliary tangent at point 3, and to make the case general, suppose the backsight to be taken on point 1.

In Fig. 7 let T′T = primary tangent; S = point of spiral: 1, 2, 3 = extremities of chords; AB; CD; = auxiliary tangents; s = sum of central angles, subtending chords up to point 3 = inclination of CD to T′T. E = interstction of AB and CD. Required: Angle C31.

$$\begin{aligned} \text{Now angle } C31 &= BE3 - E13. \\ &= CEA - E13. \\ \text{But } CEA &= TC3 - CAE. \\ \text{Therefore } C31 &= TC3 - CAE - E13. \\ &= S - S_1 - E13. \end{aligned}$$

This result may be expressed as follows: At any point, the back deflection (or deflection from auxiliary tangent to back point) is equal to the *sum* of the central angles up to the forward point *minus* the sum of the central angles up to back point, *minus* the forward deflection from the back point to the forward point.

Having found the auxiliary tangent the circle may be located in the ordinary manner; or, if the spiral has to be continued farther, the deflections from this auxiliary tangent must be calculated from the inclination of the chords to this tangent as in the case of the primary tangent.

The inclination of the chords to the auxiliary tangent may be found directly from the central angles, as with the primary tangent, or if the inclinations to the primary tangent have already been found, then the inclination of the chord to the primary tangent *minus* the inclination of the auxiliary tangent to the primary tangent, is equal to the inclination of the chord to the auxiliary tangent. Thus far only one way of varying the curvature of the spiral has been shewn, viz. :—by varying its length. A moment's consideration will shew us that this method will not do in practice. Suppose a spiral has to join a 4° curve, then t = no. of chords = $\frac{4^\circ}{10'} - 1 = \frac{240'}{10'} - 1 = 23'$, or length of spiral would be 2,300 feet, a length never desirable and seldom available.

In order that this curve may be of any use in practice, the curvature must vary independently of the length, or in other words, the spiral must be made capable of being constructed on different scales.

Since curvature depends on the relation between an angle at the centre of a curve and the arc or chord subtended by it, it is evident that the curvature may be varied in two ways; either the central angle may be varied, the chord length remaining constant, or the central angle may remain constant and the chord length varied, the curvature varying, practically, inversely as the chord length.

By the first method, since the central angles are varied, therefore, the inclination of the chords and the auxiliary tangents to the primary tangent are also varied, and consequently the deflection angles are varied. By the second method the above mentioned inclinations remain constant, the only variation being the length of chord used.

As it is much easier in practice to vary the length of the chain than to make the calculations which have been shewn necessary to find the deflection angles, the second method is much the better one. It has also these advantages in practice, that the points are comparatively close together (from 10 ft. to 50 ft. apart), and that owing to the shortness of the chords, the available length for the spiral may nearly all be made use of in case curves are close together.

We have just found that when the central angles are kept constant, all the other angles about the spiral are also kept constant, consequently, we may calculate, once for all, and tabulate for each point, all deflections (whether forward or backward) to all other points. Tables so constructed including points from S to 20 will include all cases which will arise in practice, as S at point 20 = 35°.

As the curvature varies with the length of the chord used, the curvature corresponding to each chord may be calculated for any chord length. Consequently a table may be prepared, containing for each chord length used in practice the corresponding degree of curvature for each chord. In practice the chord length varies from 10 to 50 feet, with intervals of 1 foot.

Let us see what these tables will enable us to do.

Suppose the degree of the circular curve to have been decided on. In the table for chord lengths we will find several chords of different lengths corresponding to a curvature closely approximate to that of the circle, and from these we may select the one of length best suited to our particular case.

Having selected the spiral, the table of deflections will enable us to locate it, provided we know the position of S and the direction of the primary tangent.

The position of S or the distance from the intersection of the primary tangents, depends as with ordinary curves, on the inclination, or intersection angle, and must therefore be calculated for each particular case. It is found by the following method :

In Fig. 8 let T = intersection of primary tangents ; R = radius of circle ; S = point of spiral ; s = central angle of spiral ; SL = spiral ; O = centre of circle ; LH = $\frac{1}{2}$ circular curve ; join OT and OL ; draw GLI parallel to TS ; draw GN ; LM ; OI perpendicular to TS. Required :—$T_s$

Then $IOL = S$ ; $IOT = \frac{1}{2}K$ ; $OL = R$ ; $SM = y$ ; $LM = x$.

Now $T_s = ST = SM + MN + NT$.

But $NT = GN \tan TGN = x \tan \frac{1}{2}K$.

$$\text{And } MN = GL = OL \frac{\sin LOG}{\sin OGI} = R \frac{\sin(\frac{1}{2}K - S)}{\cos \frac{1}{2}K}.$$

$$\text{Hence } T_s = y + x \tan \tfrac{1}{2}K + R \frac{\sin(\frac{1}{2}K - S)}{\cos \frac{1}{2}K}.$$

As x, y, and S are involved they should also be inserted in the tables, and as they have to be found in order to calculate the tables, no extra calculation is necessary. Tables such as have been here indicated, containing deflections and chord lengths of from 5 to 50 feet, have been prepared, by W. H. Scales, C.E.

## FIELD WORK.

In nearly all cases the location of the line may be carried on in the usual way, but before cross-sectioning or construction is commenced the spirals should be located and the necessary changes made in circular parts. The curves should be made to "come out right" even if K and $T_s$ have to be remeasured. The points S and L should next be carefully established or referenced.

As the spiral is constructed on a number of chords of equal length, it must be located irrespective of the regular stations. For convenience when cross-sectioning, however, it is well to have the regular stations located.

When it is necessary to interpolate a station it may be located with sufficient exactness by making the sub-deflection equal to the sub-chord. For general purposes, however, stations may be located by the eye.

When final track centres are given, no points but extremities of chords should be located. The points S and L should be permanently marked by monuments at the side of the track, lettered for future guidance of trackmen, shewing the distance to the centre, and the elevation of rail. If one or two intermediate points were fixed in the same way it would secure a proper adjustment of the track.

J. L. Allison.

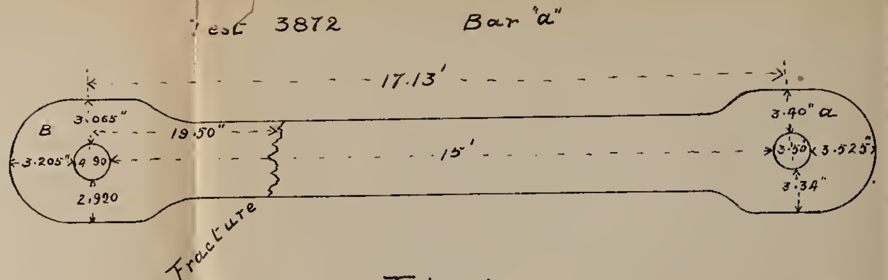


Fig. 1

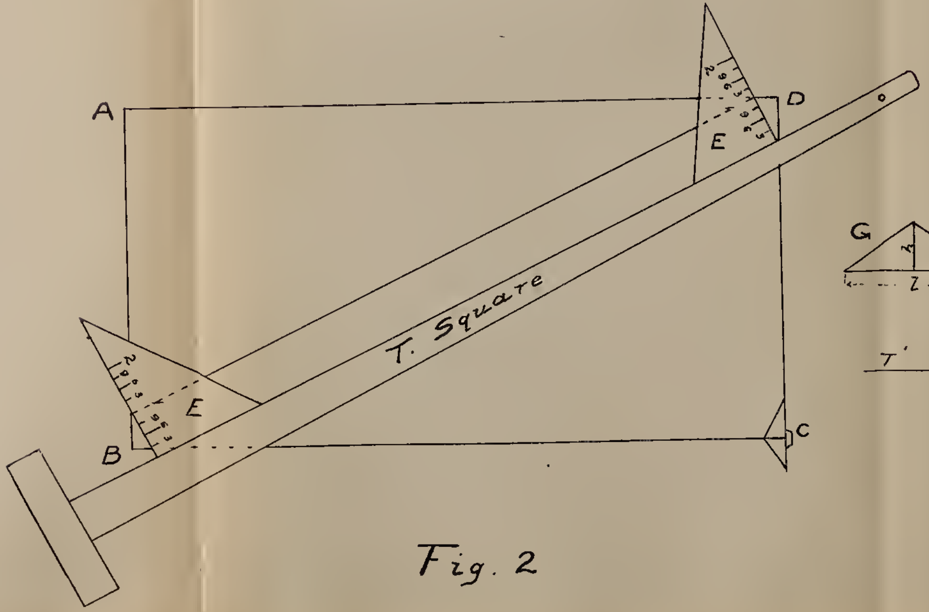
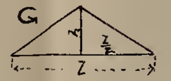
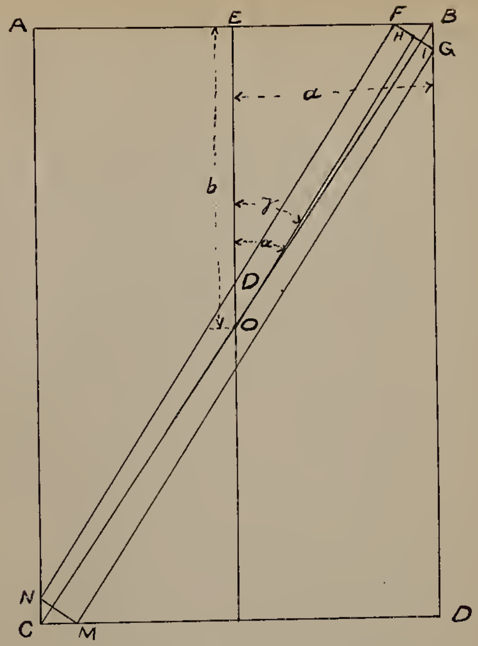


Fig. 2





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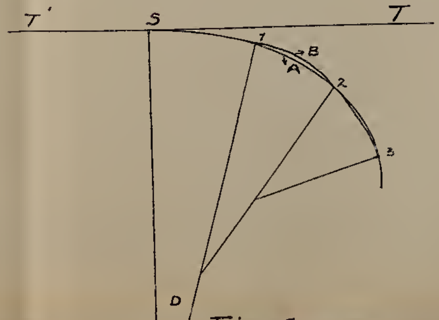
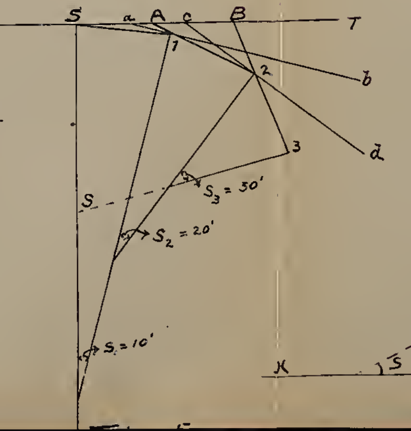


Fig. 4



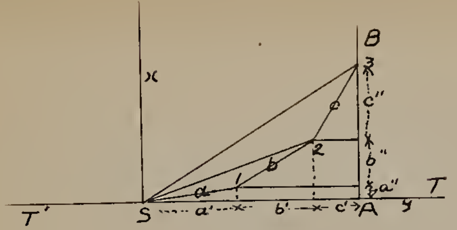


Fig. 6

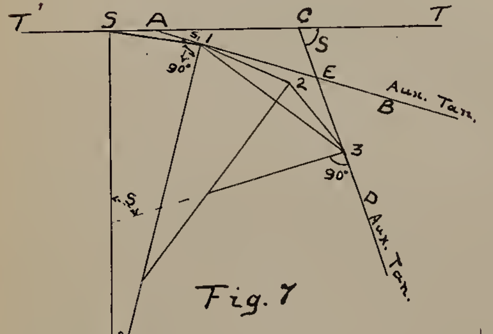


Fig. 7

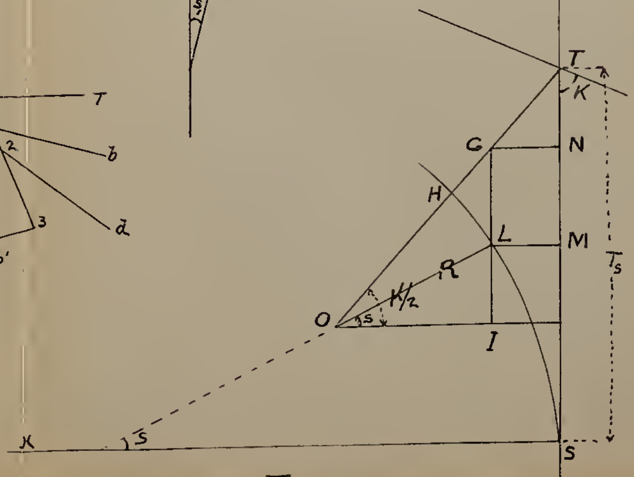


Fig. 8

No. 3. 1889-90.

# PAPERS

READ BEFORE THE

# ENGINEERING SOCIETY

OF THE

# SCHOOL OF PRACTICAL SCIENCE

# TORONTO

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# PREFACE.

THE Engineering Society of the School of Practical Science was founded in the Spring of 1885 through the exertions of a few of the students in the Department of Engineering, Messrs. Herbert Bowman, of the third year, and T. Kennard Thompson, of the second year, being the principal promoters. Meetings are held every second and fourth Tuesday of each month during the session, at which papers are read and engineering questions discussed. In order to keep alive the interest of graduates in the success of the Society some of the leading papers contributed during the previous session are published annually. It has been thought that the interest in these papers would be increased if they were published as soon as possible after being read. This edition, therefore, contains not only the principal papers read during the session of 1888-89, but also those read during the first term of the present session. The majority of the writers are students, the greater part of whose time is necessarily spent in acquiring information already in the possession of the profession, and who can ill afford to spend much of it in original investigations. Notwithstanding this, however, most of the contents of the papers are the results of their individual observation or experience, or at least the writers have some practical knowledge of the subjects dealt with.

It is hoped by the general committee of the Society that graduates of the school and former students, who are now engaged in active work, will make endeavours to contribute papers relating to their work to be read at meetings of the Society.

The present edition consists of one thousand copies, which will be widely distributed among Engineers and Surveyors.

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# ENGINEERING SOCIETY

OF

# THE SCHOOL OF PRACTICAL SCIENCE

TORONTO.

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## PRESIDENT'S ADDRESS.

*Gentlemen :—*

In reading over, some three weeks ago, the inaugural address of the president of the British Association, on " The Civil Engineer and what he has done for the Advancement of Science," I hesitated whether it would not be the best thing to read that instead of my own. I decided not to, because I thought it would be a bad precedent to establish, and, besides, you can all read it for yourselves.

I must ask your pardon, gentlemen, for the disconnected way in which mine is written. I feel greatly the lack of experience, and the poorness and weakness of many of my ideas and arguments. I have not spent sufficient time and thought on the subject. I only wish I had some six months more in which to improve the crude ideas I have now, and to connect them in some more intelligible way. I believe it is customary in an inaugural address to sketch the advances made during the past year in those subjects to which the Society devotes itself. This is highly interesting and instructive to those who are in actual practice and know the condition of affairs at the beginning of the year, but to us, who are still at the theory and know very little of the actual practice of engineering, I think it would be more interesting to devote ourselves to the subject of our own Society. To those who are coming here for the first time, I think some explanation of the objects of the Society is due.

To begin, then, with the history of the Society. The Society was founded some three years ago—in the Spring of 1885. It was called " The Engineering Society of the School of Practical Science." It is a students' Society, and only those connected with student life in the School of Practical Science and the University of Toronto are admitted as ordinary members.

The objects of the Society according to the Constitution are :—

1. The encouraging of original research in the Science of Engineering.
2. The preservation of the results of such research.
3. The dissemination of these results among its members.
4. The cultivation of a spirit of mutual assistance among the members in the practice of the profession of engineering.

Meetings of the Society are held twice a month ; at these meetings, papers on Engineering and Scientific subjects are read by students and professors, and also general discussions are held on various subjects. Periodicals on the various branches of engineering are subscribed for by the Society and these are circulated among its members.

Two years ago the more important papers read before the Society were printed in the form of a pamphlet in an edition of 500 copies, at a cost of $90—$60 odd of which were paid for by advertisements. Last year an edition of 1,000 copies was published at a cost of $112—some $55 of which were met by the advertisements. These pamphlets are exchanged with other engineering societies. The fame of the Society has spread far and wide owing to the distribution of these pamphlets. Only the other day we had a letter from a library in England asking for some copies.

The Society has 137 ordinary members and 4 honorary members. The officers of the Society are President, Vice-President, Secretary-Treasurer, Corresponding Secretary, and five representatives—one from each year, and from the special students and from the graduates. One of these representatives is Librarian. The annual fee is one dollar.

Thus, you see, gentlemen, that our Society is in its fourth year. It is firmly established here and will last as long as there is an Engineering Course in the University of Toronto.

Thus, in arranging our plans for the future, we must take into consideration that they will benefit not only ourselves, but the next few generations that are going to follow us here. Think of what value and interest these papers and periodicals will be one hundred years hence ! Think of the opportunities we have, and, consequently, the responsibilities which devolve upon us.

Now, gentlemen, as to the objects of the Society. Of course *the* object is to benefit its members, a selfish object perhaps, but, nevertheless, *the* object, and the ways and means of attaining this end, and the prospects and probabilities of the result are what I want to discuss this afternoon. The question is: In what manner can we best benefit ourselves? It certainly must be a benefit to our brain and reasoning powers, not physical benefit or mere pleasure that we must seek after. What are we all here for? What is the object of spending three years of our life at this school? To get a diploma you say. Well, I suppose it is; but what does getting a diploma entail? Does it mean only the learning of some few facts and formulæ and methods? *No*, it means learning to *think*, to reason aright, as well as these facts and formulæ. Can we do better than assist ourselves in learning to *think*?

Gentlemen, how many of us can hit the bull's eye at five hundred yards with a rifle? Not one of us unless he has had a great deal of practice. Some of us might hit the target at fifty yards. We all can at least fire off the rifle, and in time would hit the bull's eye. So with thinking; we can all think just as we can fire off the rifle, but how many of us can think and reason accurately and clearly about the harder problems which crop up every day? Just as we can't walk a tight rope without practice, so with thinking—we can't think without practice.

Let us take a hypothetical case. Suppose it were possible to attend all the lectures, get up all the facts and formulae and methods, pass the exams and get the diploma without being able to think and reason accurately and clearly; would it be of any use? *None whatever.* And again, won't he who is able to think best and reason and make his deductions from the facts and formulæ most easily, won't he be far better off than the others?

It is in these meetings where we have to think on subjects that are not fully treated of in any one particular book, where we have to exercise our ingenuity and originality, that we get our practice of thinking.

Gentleman, what was our Euclid for? Weren't we told that it was an exercise in thinking? Take our course here; we have the reasoning in the abstract pure and simple—euclid and algebra. That is, we are taught a way of thinking. Next we have our statics and dynamics showing how this way of thinking may be applied to matters concrete.

Again, our analytical geometry—conics—another way of thinking and looking at things; and, again, the application of this in the theory of the strength of materials; and still, again, our calculus, something entirely new to us in reasoning and thinking. This shows the necessity of knowing how to think.

Another thing—clearness of thought. How often when we have read a thing, that is, followed out somebody else's thoughts and reasoning, we think it is quite easy and plain, but when we come to write it out or explain it to someone else it is not quite so easy and so plain. We leave out steps, we get " muddled " ; due, gentlemen, to a lack of clearness, to a bad way of thinking. There is nothing so conducive to clear thinking as writing or explaining to others. This the Society gives ample room for practice in.

Again, gentlemen, we don't all look at things in the same light. We look at this in widely different ways. What is the result ? When the ways are made known we see that it is possible to see things differently and to attack them from different sides to those we have been accustomed to, and consequently our minds gradually begin to look at things not only as they used to but as some others do. Thus, there is less chance of mistake ; in fact our minds become broadened. If there is one mistake that we ought to fight against with all our might it is *narrow mindedness*, and the tendency to run in fixed grooves. This can be greatly overcome by the exchange of ideas, and the open discussion of various subjects.

Again, gentlemen, we are too fond of doing nothing but reading books and following lectures. That is, we only follow other people's ideas and reasoning—very good as far as it goes—but in this way we practise our own thinking powers very little indeed. There is no originality, and when we are left to ourselves we are at a standstill. We can follow a game of tennis, and see how every stroke and rally and everything is done, in fact, know all about it, but when we come to take the racquet ourselves, where are we ? Here, again, the Society helps us greatly. It give us opportunities for original thought. So much for the improvement of our thinking powers.

Now, there is another thing which the engineer requires very much, that is, the power of observation. The observing of facts and methods, and the remembering of them, and the power to reason about them, and to base deductions on them, and to draw logical conclusions from them. This is most necessary. To be able to reason and think we must have a foundation of facts to go upon. These the Society can give us. In the Society all may get the benefit of the reading of one. Thus, you see what a large amount of knowledge we can get together ; also, by means of our magazines. Books concerning the practice of engineering in this age of rapid advancement are always behind the times. Experimenting men have not the time to write a book, and even if they had they are not willing to take the trouble over it till they have finished their investigations. But a short magazine article can always be written, and is generally upon the very latest developments. Magazine reading gives us the latest facts and methods, opens our minds and gives us subject for thought. We get ideas in magazines that we never get in lectures, and ideas of great value to us.

Another thing, and here, I think, the Society can help us wonderfully, and in a way we could not get in books or in years of thinking. I mean, that if we possessed in our library copies of plans and specifications, estimates and contract forms connected with engineering, also such original tables as Mr. Russel gave us last year, and also plans of culverts, small bridges, drains, sanitary appliances—in fact anything of that kind, it would be of great use to us.

There are yet ways in which the Society can help us. Many of us come here from the country, I know I did, not accustomed to associate with many other fellows, not accustomed to make our ideas known to others by writing or speaking, never having had to speak before an audience. Here is the place to learn to do this, here, where there are no strangers, and where we are all in the same position. It will be of great use to us in after life. Here also we are all together with one common aim, the only time in which we are. Here, gentlemen, we all meet on an equal footing; the first year has equal privileges with the third year, and though perhaps not so much can be expected of them, still we certainly shall expect them to take part in the discussions, and give us an occasional paper with the results of their own experience and observation.

Now let us run over the advantages of the Society to its members:

1st. It affords practice in thinking.

2nd. It tends to clearness of thought.

3rd. It tends to originality of thought.

4th. It widens our minds.

5th. It tends to make us more observant.

6th. It gives us opportunities of seeing the actual practice of engineering through the magazines.

7th. It can give us access to plans and forms and other things which in no other way we could get.

8th. It gives us practice in public speaking.

These are all I have mentioned. The next question is—How are we going to make the best of each of these possible advantages? Let us take them up one by one.

Firstly—Practice of thinking. This depends on each of us individually, but still if only one of us were to practise he would not do nearly so much as if the practice were more general. I mean thinking leads on to more thinking, and the more general the thinking the more active will the thinking be individually. We must each of us take up every subject for discussion and work at it and think about it, and see if we cannot find out something about it that will be new to the others ; and even the papers, we must not leave it entirely to the writers, we must at least find out enough on the subject to be able to appreciate it and to make an interesting and instructive discussion on it afterwards, and if we can't find out anything on the subject we can at least find out points about which we are ignorant, and ask questions. Don't be afraid to ask questions. If we don't think ourselves we can at least set the others thinking.

Secondly—It tends to clearness of thought. A most important thing. We can't depend on our thinking if it is not clear. We can't trust ourselves. We never can know whether we are right or wrong. The hurried way many of us have of reading our books is very likely to produce lack of clearness. It is easy enough to follow the reasoning of the author, and we are too apt to imagine we see things when we don't. How often have we found great trouble in writing out a proof in an examination which we saw so clearly when reading it over before. This writing of our thoughts is extremely good for us. How often we are unable to explain to others what we think we see so well ourselves. By writing papers and preparing for the discussions and taking part in them we can help ourselves greatly to get out of this bad way of thinking.

Thirdly—It tends to originality of thought. This, gentlemen, in the engineer is most necessary. At every turn in his work problems crop up that have to be treated differently from anything he ever heard. or read of before. As I said before, we do very little but follow the reasoning and thoughts of others. This is all very well as far as it goes. When we were learning to swim we had a float of some description to help us, and how well we could get on with this help ; but directly we left go we lost confidence and sank. The tendency of fellows working for examinations is to let all original thinking go and to follow only the lectures and text-books ; and we get so out of the habit of thinking for ourselves that when we come to something entirely new we are floored. Again and again have I been going over somebody's notes of a lecture a week or so old and we have come to some step or steps that we could not follow, and which, to us, were evidently wrong. "Oh," my friend would say, "that is what Professor got, it must be right." He had more confidence in his eye and ear and power of writing correctly than he had in his own thinking powers. We should be so practised in thinking out everything for ourselves that we would far rather trust our reasoning than our sight or hearing.

One good example of original thinking is in the solution of "deductions" in Euclid. How easy it is to follow the propositions in the book? How difficult to work out the most simple deduction for ourselves until we have had practice! The Society makes us think for ourselves. We discuss subjects upon which we have neither books nor lectures. We *have* to think for ourselves.

I think I am taking up rather too much time on this "thinking," but I have so felt the necessity of it myself that I feel as if I could not impress it upon you too strongly. I would like to skip the next point for the present and take the fifth and third together.

Originality of thought and observation. They work together; the more we observe the more do we think upon what we observe, and the more we think about these things the more we observe, and the more closely. It soon becomes natural for us to ask "why" or "how" about everything we see. One would be inclined to think that we would be interrupted continually by these questions, but the question comes up and is answered almost unconsciously if at all simple, and we have added something to our experience almost without knowing it. There seems to be an undercurrent of thought which goes on unconsciously, and which seems to work with memory. We ought to cultivate to the utmost of our ability this power of observation. It ought to be as necessary to us as being able to read. An aid to our observing is a subject for us to think and observe upon.

Now, the Society has its discussions. What better inducement could you wish for? The subject for discussion is always announced at least a week beforehand and sometimes a month or more. Besides the discussions the members are at liberty to ask questions, and the more questions asked the better. It makes the others think.

Now, gentlemen, rake up questions; don't be afraid of their being too simple, but ask questions on everything that comes under your notice that has anything whatever to do with engineering.

Now, to come back to number four. It widens our minds. How important to the engineer, more than anyone else, is the wideness of his mind! I think that you will all admit that studying with the object of standing well in the examinations tends to narrow mindedness. Now, gentlemen, how many of us are studying with this object in view? By far the larger number of us. Now, if the Society can help to counteract this tendency it will benefit greatly a large number of us. Now, the number of widely different subjects discussed before the Society, and the different opinions and experiences on every subject, must help to counteract this. I would like to say more on this, but have not the time.

Sixthly—It gives us opportunities of seeing the actual practice of engineering through the magazines. Now, as I mentioned some time ago, magazine reading makes us observe and think more, widens our views and gives us a large number of practical facts and methods. We hope, this year, to make our stock of magazines of more benefit to the members. We have obtained the use of a small room downstairs, and the General Committee are having it fitted up with shelves so that our very large number of papers can be spread out and kept in good order, and be easily obtained.

We want to appoint a committee of three librarians, whose duty it shall be to look after these, and to take certain days for the distribution of them, They will keep a book, and every member's name will be entered, and the numbers of the copies he takes out. Thus, there will be no trouble in getting the papers as there has been in other years. Besides these old copies, we hope to take in several new periodicals. I think it would be advisable to appoint a committee to investigate and find out the best periodicals, and to appropriate a certain amount to be spent by them. We should have papers on the various branches of engineering; railroad engineering, architecture and sanitation, mechanical and mining engineering, besides general scientific papers.

Seventhly—As to these plans and documentary forms—Members last year were asked to obtain or make tracings of anything they came across in their office work; also to make or obtain copies of any contract forms, specifications, etc., and present them to the Society. As yet I don't think any have been sent in. Now, if we had a good collection of these, besides catalogues of instruments and books, lists of engineers and companies to whom we might apply for work, patent laws and regulations, prospectuses of engineering schools throughout the world, copies of field-notes as kept by different engineers, etc., etc., and any general or particular information that would be useful to the young engineer, it would be of great advantage to us. In fact the library should be a complete reference book on all subjects connected with the engineer. I think in this way the library can do a great deal of good at a very small expense. The best way to proceed would be to appoint a committee to investigate the matter, and let them report to the Society, and the Society can then give them power to act.

Now, we come to the last—It gives us practice in public speaking. Never again, gentlemen, shall we have this opportunity. Once we are graduates we shall have no more student life; our meetings will be in public, we shall be among strangers instead of companions and friends. So, gentlemen, let us make the most use of our time here, and cultivate to the best of our ability this most useful accomplishment.

In closing, gentlemen, I would say that the more activity and life in the Society, the greater will be the advantages derived from it. I would like to impress it upon you all that it does not depend upon the General Committee or on the readers of papers, or on anybody in particular, but on the individual effort of each and every member.

Gentlemen, let us read, observe, and, above all things, think, and give to the Society that which is due to it, and let us strive to the utmost to increase tenfold the usefulness of this, our Society.

*October, 1888.* H. E. T. HAULTAIN.

# A SHORT HISTORICAL REVIEW OF SANITARY SCIENCE AND THE "GERM THEORY."

By Cesare J. Marani.

> "We live, we die, live well or miserably, live our full term or perish prematurely, according as we shall wisely or otherwise determine."

What is Sanitary Science? It is an application of the laws of physiology and general pathology to the maintenance of the health and life of communities, by means of those agencies which are in common and constant use.

What is Sanitary Drainage? It is *one* of the principal agents in bringing about the above desired conditions.

Has Sanitary Science been in existence for many years, or is it of recent origin? To this we would answer that though Sanitary Science might at first appear to be of recent origin owing to the wonderful development it has undergone of late years, and to the strong onward impulses it received about thirty years ago from the labours of such men as Lyon Playfair, Smith, Edwin Chadwick, Southwood and others, it can be traced notwithstanding this, through the filth, dirt, and darkness of the Middle Ages, through Rome's triumphant days, through that memorable epoch when Egyptian architectural skill was at its best, right back to the earliest Persian and Chaldaean dynasties. The Mosaic code of Laws—the most ancient on record—shows that the health of the Jewish population was a subject of no small interest in as much as it was a subject of legislation. (Leviticus, xvi. 37-42; Deuteronomy, xxiii. 12 and 13.)

Space prevents the giving of even a short account of the growth of Sanitary Science from these early times. How its importance rose or fell, how its dictates were carried out at certain times or altogether abandoned, according as the monarchy became powerful, imperative and rich, or sank in consequence of wars and defeats into inactivity and subjection; how it has undergone many a severe collision with superstition, custom, and pagan idolatry, and what the consequences have been; how certain ideas were put to test, certain symptoms carried out and what resulted from them; all this and more would take up as much space as George Rawlinson's "History of the five great Monarchies of the ancient Eastern World," published in three volumes, and could not therefore be introduced here.

We know of no book published containing an arranged compilation of all the facts recorded from the earliest times relating to, or bearing in any way on Sanitary Science including, of course, Sanitary Drainage. Such a book there may be, and certainly there should be, since there is more than ample material in that direction. For the present the inquisitive student must be willing to wade through numerous translations and reprints of old records, most of them written for an entirely different purpose, and filled with other matters. This then necessitates a great deal of judicial reading, and proves the truthfulness of the old saying, "There is no royal road to learning"; but nevertheless the reward is more than can be anticipated before the start is made. He will find that the onward progress of Sanitary Science with its peculiar variableness of speed takes place right through the history of the world. There is only one place where it seems to have retrograded like most other good things, and that is during the "Dark Middle Ages." *We* should be thankful to find ourselves beyond the influences of that "Slough of Despond." Like a small silver thread of limpid water among some rugged mountains —the early races of humanity—we find our little rivulet of Sanitary Science battling against, and being often turned aside owing to its feebleness, by the rocks and pebbles of barbarism and superstition. Notwithstanding these and other obstructions, as want of experience and facilities for observation, we follow it as it gradually finds its way towards certain depressions,—the basins of learning in those early days.

It increases in size and momentum when a crowned head begins to discover the inert virtues that lie hid in its waters and sets about straightening the channel and facilitating its onward flow—like King Khammarabi. Further on we find our rivulet arrested and almost hidden by marshy grounds and lofty reeds—which represent on the one hand, the inactivity and stagnation that often overtook the different empires of the Old World, caused largely by those terrible wars into which they would dash, regardless of life and everything else, every robust male being called to fight, while women, children, and the sick were left to carry on the sanitary works and the affairs of the state; and, on the other hand, the smothering effect that their tyrannical systems of government had on scientific research and science at large. Happily for us, we find that our stream breaks forth at last from these destructive surroundings and resumes its onward flow towards a gap in the mountain tops, where, after leaping down a considerable height, it strikes on some projecting rocks—the religious customs and superstitions that sprang up in the Eastern World just before the invasion by the rising Greeks—only to dance off again with greater fury, forming a serpentine course down the valley of human civilisation. As we turn the pages of history we find it gradually assuming the dimensions of a river. We find the Laws of Lycurgus, and such men as Hippocrates, the celebrated physician, saving lives and even whole towns from certain plagues, then rampant all around, by forcing the dictates of sanitary science to be put into immediate execution. His cardinal hygienic formula, so well known to everyone, stands unalterable even unto this day. How promising, important and indispensable is this, our river of life-giving principles, as it flows past the highest and boldest cliffs of Roman supremacy! Among ancient nations the Romans seemed to have been fastidiously clean, both in their persons and in their dwellings. They made free use of water, and were fond of the bath. They were also the first, as far as we can ascertain, to use the water-closet. They made the Campagna ot Rome as healthy and fertile as any of our best fields to-day by a good system of drainage, the importance of which they very well knew. These drains were afterwards allowed to go to ruin, and to-day the same Campagna is the source from whence springs up what is so well known to all travellers as the " Roman fever." They even had their Cloacae well ventilated to the end that pure air might oxidise and destroy the poisons arising in the gases given off by decomposing sewage. Even before this the Roman people, notwithstanding their military occupations, found time to build what now stands as an indestructible memorial of their knowledge and attention to sanitary matters, namely, the " Cloaca Maxima."

The ruins round Rome substantiate this, and also show that aqueducts were made to cover miles of the surrounding plain for the purpose of supplying Rome with an abundance of pure water that was beyond the slightest doubt untainted by sewage in any shape or form. They even founded a college of the *Archiatri Populares* or state physicians, whose duties were to look after the health of the public, and this may be regarded as the earliest type of our General Medical Council. Can we not then justly attribute a great deal of the glory, learning, and success of the Romans to their quick apprehension of the vital importance of Santary Science and Drainage at large?

But ah! Further on our fair river widens, and where the Roman crest sinks, and receding backwards is lost in the surrounding hills, we find it running shallow, losing its speed, and breaking up into several disjointed branches. Presently it seems to stagnate and vanish in the ground, and we can only find a very small and turbid stream continuing to drag its sluggish waters through the gloom and darkness of the Middle Ages.

We are indebted for the preservation of this remnant of a once flourishing branch of scientific knowledge to the rituals and peculiar customs of a church which, with all its faults did its duty and proved the best for the times, but which has since been making room for a better.

Macaulay speaking of the comparison made by some divines between the Church of Rome and the Ark, says, "Never was the resemblance more perfect than during that evil time when she alone rode amidst darkness and tempest, on the deluge beneath which, all the great works of ancient power and wisdom lay entombed, bearing within her that feeble germ from which a second and more glorious civilization was to spring." The monasteries and abbeys indeed proved a protection to sanitary science as well as to other branches of knowledge, and when at last men began to try and regain what they had lost, and things in general began to wear a different and more promising aspect, then and only then do we find our little stream, issuing from cells, cloisters, and monastic retreats, once more widening its banks of authority and increasing its power and force, until it falls a clear beneficial stream of knowledge into the grand valley of the nineteenth century. Here again it more than doubles itself owing to the boiling and surging waters that issue on every side to reinforce it, and so prolific of these springs of knowlege is the nineteenth century that our stream becomes at last commanding, irresistible, greater and even broader than during Rome's best days, and of recognized importance and value. This then is intended to give the reader an idea of the continuous though changeable flow of sanitary science since the earliest times.

The first appearance of what has now grown into a wonderful plant, stretching its many branches into as many different directions, namely the *Art* of sanitary drainage, seems to date as far back as the 16th century B.C.

Borosus, a Greek writer, informs us of the beginning of the first Chaldæan Dynasty in 2250, B.C. He goes on to show how weak and insignificant Assyria and the other surrounding countries were at that time, through illness and dearth. Some time (date unknown) before the reign of King Khammarabi, who probably reigned from 1546 to 1520, B.C., a plague broke out among the Chaldæans, caused as the writer supposes—and very justly perhaps—by the putrefaction of swarms upon swarms of locusts that had made their appearance in the land, and which had perished, partly by the overflowing of the Tigris. It must be remembered that Chaldæa was then an acrid, low, and very marshy land on the north shores of the Persian Gulf, and subject to annual inundations from the waters of the Tigris. Upon King Khammarabi's accession to the throne, the plague abated, and then disappeared, for it is recorded that the King caused a system of artificial irrigation to be adopted through the entire kingdom. I also find that he is credited with being the first man to conceive such an idea, and therefore the inventor of a system that has gradually assumed different forms for different purposes, and notwithstanding the 35 centuries of developments and so-called improvements it has undergone, has not yet attained unto perfection in its practical sense. This wonderful king also forced his people to live in better and more substantial abodes, having more windows, or rather openings, for the purpose of increasing the amount of light and fresh air in their miserable mud homes. It is a known fact in history that from this time to its fall, Chaldæa stood forth as the great parent of Asiatic civilisation.

As we pass through the history of the different ages down to the birth of Christ, we find that nearly all the plagues which visited mankind in any of the three continents—Asia, Africa, or Europe—are traceable to some hot, filthy and thickly populated spot in Asia—then the most densely peopled of the three—where it would seem, from the frightful state of things, that any compliance on the part of an individual with the simplest sanitary laws was considered a criminal offence, and therefore to be avoided by living in the most disgusting manner. For example, that horrid plague which was remarkable by fierce boils and gangrenes, and which made its last and most devastating appearance in Europe in 1665, and is said to still visit certain remote and degraded tribes in the East, was first noticed among the northern tribes of Media, many centuries before it ever visited Europe. These people, though living to the north of the Chaldæans, their most advanced neighbours, do not seem to have profited by their example in matters pertaining to health and cleanliness, for we are informed by historians of their filthy mode of living. They never would wash, and would rather walk miles than wade through a river. They lived in mud houses without any openings except that through which they crawled in and out. They huddled together inside one of these dens, as many as could lie on the ground, to pass the night in sleep. They never went any distance to deposit their excrement, which was always to be found festering around their dwellings, and which was used, in a great many instances, as plaster to fill up the cracks and openings in the roof, thus cutting off, in the most horrible way, the only ventilation that the filthy den had. A Mercian encampment could be scented miles away. Some of the descriptions are too horrible to reproduce. Plagues seem almost like blessings in such cases.

We find that Egypt during the 194 years of its occupation by the Persians, who then gave some attention to sanitary laws, was free from a plague which is now always associated with the name "Egyptian," owing to its constancy in that country. They then carried out a system something like our "pail system," using their large earthen jars instead. They lived in well ventilated and magnificent buildings; those of the ruling families outshining even our nineteenth century productions from an architectural point of view, and Ewbank, in his work on Hydraulics, makes out that the summer chamber of Eglon, King of Moab, was nothing else than a private closet or privy, while Sir J. Gardener Wilkinson on describing the isolated little rooms that are to be found in one of the halls in most of the ruins belonging to the early Egyptians, says: "These rooms bear a striking resemblance to the before mentioned private room of Eglon." We find these people prosperous in sanitary improvements during the 301 years of the Macedonian dominion, and also during a great portion of that of Rome. About the beginning of the Middle Ages they seemed to have abandoned every rule of cleanliness and decency. Through internal derangements, wars, and other causes, they abandoned sanitary precautions, were then weakened by disease, carried off in large numbers by plagues, and at last they sank into the lowest depths of poverty and degradation. A century ago a people was to be found in Egypt living in mud huts similar to those of the Medes some centuries before the Christian Era. Their lands were scourged yearly by plagues and epidemics. The national spirit, enterprise, and desire for a better and more prosperous state of things which is to be found in most nations, seemed entirely wanting with them. Can, therefore, these people be descended from the early Egyptians of history? Alas, they are! The Fellah, whose mode of living is even more horrible and repulsive than that of any Mede centuries and centuries before, as described above, and who, with the rest of his tribe, is responsible for many of the plagues that crossed over into Europe during the Middle Ages, is none other than the true descendant of the Pharoah who inhabited the lofty palace, in the midst of the ruins of which he rears his miserable hovel.

An eminent English physician in describing the main dwelling place and fortress of Oriental plague goes on to say: " Cairo is crowded with vast numbers of inhabitants who live poorly and nastily, the streets are narrow and close; the heat is stifling. A great canal passes through the city, which at the overflowing of the Nile is filled with water; on the decrease of the river the canal gradually dries up, and the people throw into it all manner of filth, carrion, and offal, the stench which arises from this, and the mud together is intolerably offensive, and from this source the plague constantly springing up every year preys upon the inhabitants and is stopped only by the return of the Nile, the overflowing of which washes away this load of filth." But returning to Egypt as seen under the Persians, Greeks, and Romans who were well versed in sanitary laws, is it not justifiable to infer from the absence of any epidemic for such a long space of time, during which good administration and the sanitary police of the country conquered the producing causes of plagues, that the same means will be followed by the same results?

The Romans, though not the first in art and civilisation, certainly the leaders in all that pertained to luxury and comfort, were the first to use certain forms of seats and water-closets, as we have said before. Some men are always ready to deny any motive, or attribute the motive of a praiseworthy action to selfishness on the part of the actor. Such writers say that this onward progress of the Romans in the practice of sanitary precautions and conveniences was founded more on the gradual acquisition of fastidious tastes, intolerant of whatever might offend the senses, than on any systematic philosophy pertaining to the preservation of life. Be this as it may, we find them using four kinds of receptacles for the excreta. Glen Brown gives them as follows: " Close stools (lasana) in which the rich sometimes used gold and silver bowls; vases (gastra), which were stationed on the roadways; public privies (cloacina), of which Sir William Gell tells us there were one hundred and forty-four in Rome; and privies (latrina) probably for private use.'" Besides these, water-closets, with water supply and waste for the water basin, and something in the shape of a drain of some kind to carry off the excreta, were in constant use among the richer class, for Fosbroke, while writing on ancient closets, etc., says: " That in the palace of the Caesars it is adorned with marble and mosaic. At the back is a cistern, the water of which is distributed by cocks to the different seats. The pipe and basin of one still remains at Pompeii, and is like ours " (*i.e.* 1825, A.D.). We have several other writers who have made similar discoveries. Among them may be mentioned Sir William Hamilton, Sir William Gell and F. Liger. We refer the reader to their works.

In the time of Constantine (300 A.D.) and probably earlier, seats in the shape of chairs were used, having arms, backs, and legs elaborately carved.

For nearly a thousand years after the fall of Rome there seem to have been no privies used inside houses. Facilities for ventilation were abandoned, and fresh air had to find its way into their dwellings as best it might. In England no thought was given to drainage in any shape or form. Look at the old forts and towers of our feudal nobility, where in a great many cases more were accommodated than there was really room for. Soldiers, guards, pages, servants, guests, etc., had to crowd into their respective holes—for we cannot call those small and badly ventilated dungeons of darkness and dirt, rooms. The family of the castle, of course, fared considerably better, inasmuch as they had their own apartments. But these places were undrained, unventilated, full of impurities and noxious exhalations, and therefore, what with so many persons together and what with their dirty customs and mode of dispensing with the waste matter of the place, we can well imagine the dangerous state of things, and can heartily sympathise with those who wish they had lived in the "good old times."

We are indebted to the finer tastes and customs of our Norman conquerors for the introduction of sanitary precautions into England. We learn from Viollet-le-Duc that castles (chateaux), at the commencement of the 13th century, were accommodated with privies (latrines). They were generally to be found in a corner made by some buttress with the main wall.

James C. Bayles says: "People often wonder why we do not have such fearful visitations of epidemics at the present day as the plague of London, the ancient spotted fevers, sweating sickness, etc. They forget that we are not yet free from cholera, yellow fever, typhoid fever, and other preventible diseases, and that the next generation may see that our disregard of nature's laws affected our death rate, as surely as the dirt and filth of London caused the Great Plague." This certainly is true, still we have improved wonderfully since then, and a tremendous gap exists between our mode of living and that of our ancestors.

An old chronicler speaking about London in the 12th century says: "In the streets around St. Paul's Churchyard the horse manure was a yard deep." Cleanliness of persons was a thing unknown, and talking of the men and women in those days he goes on to say, "They wore clean garments on the outside, but dirty ones were often worn until they fell away piece meal from their unwashed bodies." Viollet-le-Duc tells us that at a considerable later period in history the people of Paris were allowed to throw their excreta from the window into the street, provided they gave the verbal warning, "Gare l'eau" three times, In Edinburgh this custom lingered till 1760 or later, and parties walking on the streets after 10 p.m. had to cry, "Haud yare hoand," every few minutes for fear of what might befall them. A writer about this time gives the following: "The High Street and Cowgate of Edinburgh, rich in architectural and historical associations, are saturated with a mass of filth which completely taints the air, and makes the stranger, as he passes through it, reflect to himself, if such be the odor which these houses cast into the open air, what must they be within? Horrible indeed are the poisoned gases with which they are filled—horrible the narrow closes, used for all disgusting purposes, by which entrance to them is found. But even in the magnificent squares and crescents, which architectural ambition has raised in contrast with the gloomy dwellings of the old fighting Scots, there are remnants of the old spirit, and "mine own romantic city" requires a thorough cleaning before it can accomplish its magnificent capabilities for purity and healthfulness." Another writer about 1831 speaks of Edinburgh as follows: "Yet when cholera presented itself in Edinburgh, the first large town where it made a serious settlement —though there had been long warning—such was the insufficiency of the sanitary machinery, that not a single particle of the filth which festers in masses or runs in thick disgusting streams through the city had been removed. Indeed it was generally observed, probably because people's eyes and noses were more acutely sensitive on that occasion, that when the cholera arrived the Old Town was more deeply steeped, than it had usually been, in loathsome filth."

History seems to show that the natural influences of thorough sanitary reforms, apart from their effect on the health and longevity of a community, are to diminish and almost expel vices, such as prostitution, theft, murder, etc.

There is no doubt that the frightful state of the sanitary condition of Paris during the end of the 17th Century and the beginning of the 18th had very much to do with the alarming numbers of those inhuman monsters the Chiffoniers, who in 1830 must have numbered 2,000, and were conspicuous actors in the French Revolution. Similarly the sanitary condition of Edinburgh was responsible for the production of such anomalies as Burke and Hare, and for the facilities their haunts afforded them. It seems to be the rule that in general sin and dirt roam the world hand in hand. Where sin holds its sway we find dirt, and where dirt lurks there we find sin.

On the subject of cholera the Glasgow Board of Health for 1831 writes as follows: "The chief predisposing causes of every epidemic, and especially of cholera, are damp, moisture, filth, animal and vegetable matters in a state of decomposition, and in general whatever produces atmospheric impurities, all of which have the effect of lowering the health and vigour of the system and of increasing the susceptibility of disease, particularly among the young, the aged, and feeble. The attacks of Cholera are uniformly found to be most frequent and virulent in low-lying districts, on the banks of rivers, in the neighbourhood of sewer-mouths, and wherever there are large collections of refuse, particularly amidst human dwellings." Then follows a lengthy piece of advice to private individuals, with several good directions and recommendations. "In conclusion the General Board of Health would again urge the consideration, that whatever is preventive of cholera is equally preventive of typhus, and of every other epidemic and constantly recurring disease, and would earnestly call the attention of all classes to the striking and consoling fact, that, formidable as this malady is in its intense form and developed stage there is no disease against which it is in our power to take such effectual precautions, both as collective communities and private individuals, by vigilant attention to it in its first and premonitory stage, and by the removal of those agencies which are known to promote the spread of all epidemic diseases. Though therefore the issues of events are not in our hands, there is ground for hope and even confidence in the sustenance and resolute employment of the means of protection which experience and Science have now placed within our reach."

In Dr. Southwood Smith's report on the state of large towns we read as follows:—

"The place called Punderson's Gardens is a long and narrow street, in the centre of which is an open sunk gutter, in which filth of every kind is allowed to accumulate and putrefy. A mud bank on each side commonly keeps the contents of this gutter in their situation; but sometimes, and especially in wet weather, the gutter overflows, its contents are then poured into the neighbouring houses, and the street is rendered nearly impassable.

"The street is wholly without drainage of anykind. Fever constantly breaks out in it, and extends from house to house; it has lately been very prevalent here, and we have had several fatal cases from it in the London Fever Hospital. The open area called Lamb's Field is about 700 feet in length and 300 in breadth, of this space 300 feet are constantly covered with stagnant water, winter and summer. In the part thus submerged there is always a quantity of putrifying animal and vegetable matter, the odor of which at the present moment is most offensive. An open filthy ditch encircles this place, which at the western extremity is from eight to ten feet wide. Nothing can be conceived more disgusting than the appearance of this ditch for an extent of 300 to 400 feet; the odour of the effluvia from it is most offensive.

"Lamb's field is the fruitful source of fever to the houses which immediately surround it and the small streets which branch from it. Particular houses were pointed out to me from which entire families had been swept away, and from several of the streets fever is never absent"—and so on for several pages, then he ends:

. . . . . .

"I know that the verbal description of these places can convey no conception of their disgusting and poisonous condition. They must be seen, to be at all understood, and when seen everyone involuntarily exclaims: can such a state of things exist in a country that has made any progress in civilization?" This was the state of things in London not a century ago. When the improvement of sewage was actively undertaken in London some thirty years ago, it was found that the death rate was so much reduced, especially in the above quarters of the town, that, if the same reduction could have been made universal the annual deaths would have been twenty-five thousand less in London and one hundred and seventy-seven thousand less in England and Wales; or, by another view, that the average age at death would have been forty-eight instead of twenty-nine, as it then was.

From the above we are easily convinced that there must exist some direct relationship between disease and dirt, and this then brings us to a consideration of what is known as the germ theory of disease, which we will find to possess both interest and importance.

For a full and complete discussion of this theory see Prof. F. A. P. Bansardt's book "The Germ Theory of Diseases and its relation to Hygiene."

Of all the various diseases that affect humanity the most widespread and numerous belong to the zymotic class. This class may be sub-divided into two separate families, the Entetic and the Miasmatic, the latter being by far the more numerous in its individual members. It is with this family of diseases, namely, the Miasmatic, that drainage has more especially to deal, although in addition, drainage, as changing the moisture of the ground has its effect on many diseases belonging to a family that attack the respiratory system of the body. Scientific men, and prominently among them Baron von Liebig and Monsieur Pasteur, discovered after long and earnest laborious investigations, that the propagation of a number of epidemic diseases among the lower animals was effected by certain minute vegetable germs or miscrobes. This is now an established fact. Dr. Budd is credited with having identified the germ producing typhoid fever, while there are several who claim the discovery of the diphtheria germ. These and other investigations have given rise to what is known as the "germ theory of disease."

The theory holds that matter, *i.e.*, organic matter, while undergoing decomposition, creates or develops and gives off numerous microscopic cells of a very low order of vegetable life. The spores which proceed from these fungi are carried about in the air currents, as the invisible pollen of flowers is carried, and on coming into contact with the skin, or more especially the mucous membrane, they work their way into the veins and arteries of the body where they multiply and grow in astonishing rapidity, feeding on the blood all the while. This is the cause of disease.

Though Dr. Beale refuses some of the details of the germ theory he most certainly upholds its general principle, and therefore, this much is certain, that none of these miasmatic diseases exist without a sufficient cause, and that moreover, the cause is in every case some emanation either from decomposing organic matter, or from some diseased person. Hence it follows that diseases of this order are entirely preventible when their hot-bed and stronghold, namely, decomposing matter and rotting filth of every kind, are removed to safe quarters, and when those who are struck down with one or more of these diseases are removed to a safe distance or shut off from their fellow creatures. This conclusion should be readily accepted, for not only is it deducible from an assumed theory of diseases, but actual statistics without number leave no question as to the fact that typhoid fever, diphtheria, etc., are in every case traceable to some violation of sanitary laws, and that when these violations have been discontinued, the diseases have themselves abated and ultimately died out.

In Latham's "Sanitary Engineer" we find a statement of the relative death rates of twelve English towns before and after the introduction of sanitary works. The following are the averages of the twelve towns.

Average mortality per 1,000 before construction of work, 26.4; average mortality per 1,000 after or rather since completion of works, 21.7.

Although the separate results vary considerably, still in every single case the improvement is decidedly marked. This, of itself, as a result from works admitted to be imperfect, serves as an almost unanswerable argument in favour of the benefits to be derived from sanitary drainage.

By following on the line of speculative calculations we would get the following: The sum of the populations of these towns is almost 25,400. The average of deaths per 1,000 before sanitary works were introduced, 26.4; after the works were in operation, 21.7; leaving an average of 4.7 per 1,000 to the good.

Observing that three of these at least were saved by the sanitary arrangements, and further assuming that each death represents 730 days of sickness, we have an annual saving of 76.2 deaths, or 55,626 days, which at $1.25 per day makes a saving of $69,532.50 per annum. This at 6 per cent. represents a capital of about $1,158,875 00 or about one million and a sixth. Such a calculation, though unavoidably vague and indefinite, and although of little interest to private individuals, is nevertheless valuable to philanthropists, statesmen, and civic officials, inasmuch as it points out the immense actual losses, not to individuals, it is true, but to the community at large from not giving better attention to our subject. Moreover, they show, in however casual a way, that the question of sanitary improvements is a living one of unexpectedly large economic proportions, for narrow the probable losses down to so low a point as to leave no doubt of their being below the actual case, and we still have a result which is startling in the aggregate. Let us consider for a moment the causes which contribute to such excessive and unnecessary mortality. First among these may be mentioned cesspools. In the absence of proper drains or other system of removing the waste matters of a household, every house must have one of these. But every house must have water, and as it is the exception to find a little village provided with a system of water pipes, that first has not had a system of drains introduced, so we find that a well is necessary, either for each house, or for a group of houses. All the dejecta and wash of the household, composed partly of solids, and partly of liquids find their way to the cesspool. The solid portions of this mass of filth remain and decay—ferment perhaps—and the air is filled with the emanations from this decomposition. This forms one source of disease. The liquid portions, on the other hand, soak into the surrounding soil, and, though at first they may be rendered harmless owing to the purifying effect of the ground, yet since the supply is constant the ground soon becomes so saturated with this filth as to lose its power of purification entirely. The area of filth gradually widens and widens until the well is reached, and then the unfiltered, unpurified liquid portions of the cesspool enter the well. This forms the second cause of disease from that single institution—the cesspool.

In the one case the actual poisons are inhaled, in the other drunk, both are prolific sources of disease. Along with cess-pools we may class privy-pits, garbage heaps, stable refuse and the like. Spread over the ground such refuse is the essence of vegetable life, piled up in heaps, or hid under the ground it is nothing but a source of disease and death. The third cause of the above mentioned disease is perhaps more extensive than all the others put together. It operates in cities and towns that have a system of drainage, and consists in defects of various kinds in that system and in its practical application. The possible defects are almost countless in number, and therefore the devising of measures to remedy them forms the body of the whole science of sanitary drainage. It is more important that the whole system of drainage in a house be air-tight than that the pipes of a steam engine be steam-tight, for the simple reason, that when a steam pipe leaks, the leak is manifest, not so with a sewer pipe; nothing gives warning to the inmates of the house of the existing defect save disease and death. For this reason frequent and rigorous inspection should be made of the whole system inside the house, as every inch of pipe is responsible for the whole danger. Care and thought should also be exercised in choosing the materials to be used for house drainage. The fourth cause of the unnecessary amount of prevalent disease is the want of proper drainage for the foundations and cellars of houses, and the grounds around them. With ground of a porous nature, drainage is sometimes unnecessary, but this should be looked on as a rare occurrence. The ground is generally saturated with moisture which escapes in the form of damp mists during the evening and early part of the night, and as dampness and mist are known to be very good distributors and cultivators of whatever poisonous germs may be floating about, it is to our interests to remove them from around our dwellings. To want of drainage of this sort has been traced consumption and pulmonary diseases generally, dysentery, ague, fever, malaria, neuralgia, etc. Lastly the fault may be in the main sewer itself, which perhaps is not far enough below the level of the cellars to prevent flooding after rain-storms. Toronto has experienced this flooding of cellars by sewage several times within the last ten years. These then are a few of the considerations to be taken into account in planning a system of drainage for a community, and it is evident that although a system of drainage is a vast improvement on no drainage at all, yet that the system, to be efficacious, must be complete in every detail and managed with almost scientific accuracy in every house. This also shows the necessity of considering the best means of eliminating so far as possible these dangerous liabilities so to speak, from our houses and towns.

These last twenty years have seen wonderful changes. Modern thought and enterprise has brought forth one hundred fold. Almost all these liabilities have now been lessened, and in some cases entirely moved from among us. Speaking in a figurative sense, we live in an autumnal age. We enjoy the fruits of knowledge planted and husbanded by preceding generations. Had these ages never passed on the pinions of time, and were *this* the first age of the Earth's inhabitation by man, we might find ourselves no better off regarding sanitary matters, than the Medes and Persians were before the Roman era.

Still because we have made creditable advances in all the branches of sanitary science, let us not rest, and say "it is sufficient," for then peradventure a winter of barrenness might follow on the heels of our fruitful age, and the next generation might justly impeach us with having added nothing to the World's Monument of experience and discovery. Rather let us be philanthropic, and in *that* spirit remember our school's motto *Scite et Strenue.*

## Books of Reference.

| | |
|---|---|
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| Habitations of Man | Viollet-le-Duc. |
| Encyclopædia of Antiquities | Rev. Thos. Dudley Fosbroke |

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|---|---|
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# CABLE RAILWAYS.

By E. W. Stern.

Cable railways are no longer an experiment ; already there are in the United States 200 miles of road in successful operation, and just recently they have been introduced into Great Britain, Australia and China—Hong Kong having a short line running.

The idea of the application of a rope or cable to the drawing of vehicles is by no means recent. In England, as far back as 1788, boats were drawn up and down inclines by means of ropes, but it was not until 1858 that the first patent on our modern cable system was obtained—J. H. Gould, of Philadelphia, in that year, patented the underground tube containing a movable cable. From then till 1870, numerous patents were taken out, but none were developed until that year. A. S. Hallidie, the "father of cable railways," was granted his patent for a grip pulley, and 1873 he successfully opened in San Francisco the first cable railway proper.

From the present outlook the cable tramway bids fair, in the near future, to supersede horse-cars. Statistics of those lines now in operation prove conclusively that it is the most economical and reliable system known, to handle a large and varying passenger traffic.

Its advantages over the horse-car system are briefly these:

1st. Grades are surmounted with the greatest facility and are just as easily operated as levels. This is an important advantage for the reason that it renders hill property which is the most desirable for residences, and which would be otherwise difficult of access, fully available.

2nd. The great expense involved in successful consummation of an enterprise of this nature lends tone to it, which is revealed in the improved character and cleanliness of the cars ; the substantial character of the work required results in an improvement of tracks, which altogether, increases the comfort and pleasure of the passenger.

3rd. The immense amount of filth that is due to the use of the large number of horses employed in street car lines is entirely obviated. It is much easier to keep the streets clean, and in a large city this is a matter of great importance.

4th. Increased speed.

The great drawback to the building of a cable line is its immense initial cost, which ranges from $125,000 to $210,000 per mile, including rolling stock, buildings and machinery. The cost of four miles of the Metropolitan Street Railway of Kansas City was $800,000. The Grand Avenue Cable Railway, seven and a half miles long, cost $1,200,000.

A comparison, however, of the profits derived from the cable line with those of horse-car lines and elevated railways will show its financial superiority as an investment.

Comparing the horse-car lines of New York city with the cable lines of San Francisco, we find that in 1886 the former, which aggregated 856 miles and which cost $56,906,000, produced a net income of $1,937,000, or 3.6 per cent. In San Francisco six miles of cable railway, which cost $900,000, yielded an income of $135,000, or 15 per cent. on the original outlay.

In 1886 the forty miles of elevated steam railway in New York and Brooklyn, which cost $46.613,000, yielded an income of $1,571,000, or 3.4 per cent. In a cable road now in operation, having less than one mile of double track, and which transports less than 4,000 passengers daily, there is a dividend of 10 per cent. on an investment of $150,000. The efficiency of the power being used in overcoming the friction of the machinery and cable. The Market Street cable line, of San Francisco, shows a much greater efficiency, it being 50 per cent. The horse power required for each car is about four and one-half.

A cable railway is an immense machine from one end to the other. It involves the use of a great deal of mechanism. The engineering must be done in the most careful manner, and the principle that "the best is the cheapest," must never for an instant be lost sight of.

Faulty details and execution will cause innumerable mishaps and a great loss of money.

The road-bed is put down in the most substantial manner, and the tracks lined as carefully as a skilful transit-man can possibly do it. Errors in alignment and grade of even a quarter of an inch must be guarded against.

The line is located by driving stout hubs every 50 feet apart on tangents. Curves are run in with a transit, the deflection angles being calculated for chords eight feet long. The best practice with regard to curves in turning street corners is to compound them, beginning with a radius of 100 feet, and running it into one of 75 feet, and 50 feet radius. Points are referenced by cutting marks in the stone curbing. Bench marks are carefully located at every street corner. The two side rails and the slot rail are supported by iron yokes placed every four feet apart. These yokes, which are either of cast or wrought iron, are imbedded in concrete. In the centre of the yoke is an oval space about three feet high and eighteen inches broad, the exact shape of the section of the concrete tube seven inches thick, which runs the entire length of the road and serves as the conduit for the wire rope. This standard guage is 4 ft. 8½ in., and the distance between the tracks is ten feet from centre to centre of rope. Midway between the two tracks and at a sufficient depth to give a good flow, is a twelve-inch drain of glazed pipe, and to this is connected branch pipes from the tube wherever necessary, as at changes of grade, etc.

On the straight track, every thirty-two feet apart, are placed sheaves eighteen inches in diameter and four inches broad, to support the cable. On curves the sheaves are twenty-two inches in diameter and nine inches broad, having a flange on the bottom projecting about an inch, to prevent the cable from slipping off.

When a car is being drawn along, the grip carries the cable 8 inches clear of the top of the sheaves, and in going around a curve, it raises it 6 inches and pulls it out about 2 inches from the horizontal sheave, thus enabling it to clear the wheels easily. When it is required to switch a car from one track to another the cable is let go, and the momentum it has received is sufficient to urge it across.

The cable, which is generally 1⅜ inches in diameter and of steel, first winds three or four times around the big driving wheel (12 feet in diameter) in the engine room. Thence it passes through the tube to the end of the track, where it goes around a large sheave 10 feet in diameter, then back to the engine house, being spliced so as to be in one continuous length. At the end of the track turntables are generally put in to turn the cars around. By an ingenious device, by pulling on a lever the cable itself is made to revolve the turntable.

A great many roads use the grip car coupled to another behind it. The trucks on these cars are rigid, which causes the car to jerk considerably when going round a curve.

The combination cars, which combine the two in one, have pivoted trucks, and travel round the curves with much greater facility than the former. They are being used now almost entirely on the best roads. The Grand Avenue Cable Company, of Kansas City, Mo., have two engines of 500 horse power each, one being used while the other is kept in reserve. They drive the cable at the rate of seven miles an hour.

In conclusion, the writer, although he has not entered into details minutely, hopes to have given his listeners some account of the status and general features of a branch of engineering which bids fair to develop very largely in the near future, and which requires for its successful undertaking, engineering talent of a high order.

# SEWERS.

By E. F. Ball.

The object of a system of sewerage is to remove all refuse matter from dangerous proximity to human habitations before it has time to putrefy. The best known system is the water carriage system.

The necessity for immediately removing refuse matters is established by the fact that where such removal has been effected the prevalence of various dangerous diseases has been greatly reduced or entirely checked.

Where the gases arising from the decay of refuse matter are allowed to enter living apartments, the danger of the propagation or spread of disease is enormously increased; but although there are many cases in which sewer gas is known to leak into houses where the inmates do not contract any serious illness, yet the general lowering of the tone of the system, such as listlessness, sick headache, etc., is often apparent, though the cause is seldom suspected.

In devising a system of sewers, the following points have to be considered:—

1st. The area and physical outlines and controlling features of the district to be drained, its geological character, and the depth to which it may be desirable that the drainage should extend.

2nd. The rainfall in the district, with consideration of the maximum fall of rain in a given interval of time, and the proportion of such storm-waters that it is proposed to carry off by the sewers.

3rd. The character and extent of the water supply.

4th. The final disposal of the sewage.

It will be impossible in the present paper to consider all the points at length, but an attempt will be made to describe such points as would force themselves prominently on the attention of the Sanitary Engineer.

### DEPTH OF SEWERS.

The following figures will give an idea of the average depth at which sewers may be placed in a city:—

| | | |
|---|---|---|
| Basement or cellar below street.......... | 9 ft. | 6 in. |
| Cellar floor and covering of drain......... | 1 | 6 |
| Drain.................................. | | 6 |
| Fall of drain 2 in. in 10 ft. for 50 ft........ | | 10 |
| Fall of main sewer 2 in. in 10 ft. for 30 ft.. | | 6 |
| | 12 ft. | 10 in. |

In towns and villages these figures might be considerably reduced.

## STORM WATER.

A most important factor in the designing of sewers is the amount of storm water which it is expedient they should remove. In small towns the water had better be conveyed away by surface gutters, as the expense of providing sewers for this duty is great. In large cities with paved streets and large areas of roofs this water might be sufficient to cause damage to basements, etc., hence the necessity of its removal underground. As in small towns the water supply is generally confined to wells and cisterns, some of the storm water should be admitted to the sewer to flush it, care being taken not to flood the sewer.

## DISPOSAL OF THE SEWAGE.

The sewage is usually discharged into a running stream or large body of water whereby it is so diluted or oxidized as to be rendered harmless. Various attempts have been made to purify the sewage chemically and mechanically, but with little success, for the clarified or deodorised product is still " sewage."

Attempts to utilize the solid parts for fertilizers have not proved remunerative even in densely populated countries like England, where the value of land is very great. Irrigation and intermittent downward filtration have been successfully employed in some localities.

The latter is accomplished by allowing the sewage to percolate through a porous gravelly soil, which filters out the suspended particles and the escaping liquid is sufficiently harmless to be run into streams from which water for domestic purposes is not taken.

## SIZE OF SEWERS.

Sewers should not be larger than is absolutely necessary to carry off the amount of liquid for which they were designed, as the smaller the sewers the greater the depth of the water flowing through them, and the greater its velocity and ability to sweep away solid matters and prevent choking.

Every precaution should be taken to avoid leaks, as the escaping liquid would not only poison the subsoil, but the solid matter would be deposited in the sewer and eventually choke it.

In calculating the size of sewer necessary for a given discharge it must be remembered that the supply is not from a constant head at the upper end, but is admitted at various points. The velocity of the liquid in a sewer of uniform size and inclination will thus increase towards the outlet, and for this reason the aggregate area of the laterals discharging into the sewer may greatly exceed the area of the sewer itself. From this it will be seen that the formulæ for the discharge of pipes from a constant head are not applicable.

In providing for storm water the maximum amount that need be provided for is one inch of rainfall per hour. It is extremely seldom that such a storm ever lasts an hour, and the water may be considered to occupy double the time in entering the sewer that it was in falling. Even then it enters the sewer at different points along the line so that the rainfall near the lower end may have run off before that from the upper end has arrived. The amount of actual sewage is so insignificant compared with the amount of storm water that in designing a system of sewers to carry off this water no consideration of the amount of sewage proper is necessary.

Kutter's formula for the uniform velocity of water in pipes is $v = c\sqrt{RS}$ where $v$ is the velocity in feet per second.

$R$ is the "hydraulic radius" $= \dfrac{\text{area of wet cross section}}{\text{length of wet perimeter.}}$

$S$ is the sine of the inclination of the pipe $= \dfrac{\text{fall of pipe}}{\text{length of pipe}}$.

$c$ is a numerical constant. For a 12″ sewer with a fall of 1 in 100 it = 95; for a 6 ft. sewer, 136. For practical purposes $c = 100$, $\therefore\ v = 100\sqrt{RS}$.

For pipe running full, $R = \dfrac{\cdot 7854\, D^2}{3\cdot 1416\, D} = \dfrac{D}{4}$ where $D$ is the diameter of the pipe; $\therefore\ v = 100\sqrt{\dfrac{D}{4} \times S} = 50\sqrt{DS}$.

Let $Q$ = number of cubic feet per second discharged, then $\dfrac{Q}{\text{area of pipe}} = v$, or $\dfrac{Q}{\cdot 7854\, D^2} = 50\sqrt{DS}$; $Q = 39\cdot 27\, D^2\sqrt{DS}$;

$$Q^2 = 1542\, D^5 S,\quad D = \sqrt[5]{\frac{Q^2}{1542\, S}}.$$

Let $L$ = length of pipe,
" $H$ = fall "

then $D = \sqrt[5]{\dfrac{Q^2 L}{1542\, H}}$ = diameter of pipe in feet.

As before stated, the formulæ for the flow in pipes from a constant head are not applicable to sewers, but by changing the exponent in the above equation from 5 to 6, thus, $D = \sqrt[6]{\dfrac{Q^2 L}{1542\, H}}$, we obtain an empirical formula for finding the diameters of the outfalls of sewers, and which, if intelligently used, will be found sufficiently accurate for all purposes of sewer discharge for populous districts.

Upon the supposition that the rainfall of one inch is carried off in twice the length of time of its fall, *one half inch* of rain per hour will represent the quantity discharged.

Let $Q$ = number of cubic feet per second discharged.
" $A$ = " acres drained.

The amount of water that will reach the sewers per second equals half the amount of rain falling on one acre per second multiplied by the number of acres drained $= \frac{43560\,A}{60 \times 60 \times 12 \times 2} = \cdot 5\,A$, or $Q = \frac{A}{2}$.

By substituting $\frac{A}{2}$ for $Q$ in the equation $D = \sqrt[6]{\frac{Q^2 L}{1542\,H}}$ we get $D = \sqrt[6]{\frac{A^2\,L}{6168\,H}}$.

Let $N = \frac{L}{H}$ or the length in feet in which the sewer falls one foot, then $D = \sqrt[6]{\frac{A^2\,N}{6168}}$, or $\log. D = \frac{2 \log. A + \log. N - 3\cdot 7901}{6}$;

where $D$ = diameter in feet of the outfall of the sewer,
$A$ = number of acres to be drained,
$N$ = length in feet in which sewer falls 1 foot.

To compensate for the additional friction on curves, the inclination there should be greater than on the straight portions.

Referring to the equation $v = 100\sqrt{R\,S}$, or $v = 100\sqrt{\frac{S'}{P}\frac{H}{L}}$,

$$\left.\begin{array}{lll} \text{where } S' & = & \text{sectional area of fluid} \\ \text{"}\quad P & = & \text{length of wetted perimeter} \\ \text{"}\quad H & = & \text{fall of sewer} \\ \text{"}\quad L & = & \text{length of sewer} \end{array}\right\}\ \text{in feet;}$$

if we substitute the numerical values in this formula, and for $S'$ assume one-tenth of the sectional area of the sewer, we will have the velocity in feet per second of the low summer flow. To obtain the additional head requisite for the length of a given curve, substitute this value just found for $v$ in the following formula: $h = \frac{v\,l}{2\,r\,D}$.

$$\left.\begin{array}{lll} \text{where } h & = & \text{additional head for the curve} \\ \text{"}\quad l & = & \text{length of the curve} \\ \text{"}\quad r & = & \text{radius of the curve} \\ \text{"}\quad D & = & \text{diameter of the circular sewer} \end{array}\right\}\ \text{in feet.}$$

### INCLINATION OF SEWERS.

In order that sewers may discharge their contents promptly, and not become choked with deposit, they must have a sufficient fall. The following table gives approximately the gradients which will preserve circular sewers free from deposit, *providing they run half full:*

| | | | | | | |
|---|---|---|---|---|---|---|
| For | 6 | inch diameter, | a grade of | 1 | in | 60 |
| “ | 9 | “ | “ | 1 | “ | 90 |
| “ | 12 | “ | “ | 1 | “ | 200 |
| “ | 15 | “ | “ | 1 | “ | 250 |
| “ | 18 | “ | “ | 1 | “ | 300 |
| “ | 24 | “ | “ | 1 | “ | 400 |
| “ | 36 | “ | “ | 1 | “ | 600 |
| “ | 42 | “ | “ | 1 | “ | 700 |
| “ | 48 | “ | “ | 1 | “ | 800 |

In devising a plan to remove the sewage with only sufficient storm water to flush the sewers, the following facts will be noted:

The sewage from the houses and outbuildings will be about two-thirds the entire water supply, and about one-half this quantity will reach the sewer in 8 hours.

If the water supply be 60 gallons per head per day, about 4 cubic feet per head per day will be discharged in 8 hours, or one-half cubic foot per head per hour. This will be the maximum flow from all sources.

### SHAPE OF SEWERS.

When a moderately steady flow may be expected through a sewer, it should be circular, but when the average amount of sewage is small, and provisions has to be made for large bodies of water at times, the egg-shaped should be used.

### MATERIALS FOR SEWERS.

For sewers up to 24 inches in diameter, vitrified pipes are generally used. They should have a smooth surface, should be true in form, hard and well burned. All connections should be made at as acute an angle as possible.

For brick sewers the following extract from the specifications for furnishing sewer brick, American hydraulic cement, Portland cement, and iron castings for the Genesee street branch of the Buffalo trunk sewer may be quoted.

### SPECIFICATIONS FOR BRICK.

All bricks furnished to be of the best quality of sewer brick, true and uniform in shape, burned hard entirely through, and having a clear ring when struck.

### SPECIFICATIONS FOR AMERICAN HYDRAULIC CEMENT.

All cement of this class must be of the best quality, fine ground, quick setting, capable when made into testing blocks of withstanding a tension of 50 lbs. per square inch of section when mixed pure and exposed thirty minutes in air and twenty-four hours in water.

Should cement have to be stored, or not immediately used after acceptance, or at any time, it must be protected from the weather and kept dry, and must never be placed upon the ground.

### SPECIFICATIONS FOR PORTLAND CEMENT.

All cement of this class must be of the best quality and must be ground so fine that at least 90 per centum of it will pass through a wire sieve containing 2,500 meshes to the square inch.

The cement when made into a stiff paste, without sand, must set within half an hour from the time of adding the water, and be capable of sustaining without rupture a tensile strain of at least 250 lbs. per square inch, 7 days after being moulded. The cement when mixed with sand in the proportion, by volume, of one of cement and two of sand, and made into a stiff mortar, must be capable of sustaining without rupture a tensile strain of at least 90 lbs. per square inch, 7 days after being moulded. The test blocks will, in all cases, be removed from the moulds as soon as the setting begins and the material will bear it ; but they will not be put into fresh water before the expiration of 24 hours from the time the cement was mixed. The sand used in testing the cement will be sharp, siliceous sand, free from loam, dust, mica or other foreign matter, and will be gauged between two sieves of 400 to 900 meshes to the square inch. Cakes of the paste will also be made about one-half inch in thickness, and after immersion in fresh water for one week, their surface must show no sign of crack or softness.

Each barrel of cement must weigh not less than 375 lbs. gross weight, and on the whole quantity to be delivered, must average not less than 400 lbs. gross weight to the barrel, and under this contract 400 lbs. gross weight will be considered and estimated as one barrel. The cement must also weigh not less than 100 lbs. and not more than 125 lbs. per U. S. struck bushel, when filled from a hopper placed at a height of 3 ft. above the mouth of the measure.

Each barrel must be properly lined so as to effectually seal the cement from dampness. Should cement have to be stored, or not immediately used after acceptance, or at any time, it must be protected from the weather and kept dry, and must never be placed upon the ground without blocking under the barrels.

### MORTAR.

Whenever in these specifications the word "mortar" is used without qualification, it shall be taken to mean mortar composed of one part by measure of American hydraulic cement and two parts by measure of clean, sharp sand entirely free from loam. Where cement of another quality, or sand in other proportion is to be used, the fact is so stated in the specifications. All mortar used on the work shall be carefully and thoroughly mixed dry and wetted up only as needed for immediate use. No mortar which has begun to set shall be retempered for use.

The engineer will give especial care to the thorough emptying of all vessels in which mortar may be mixed, carried or deposited, to prevent the use of even the smallest portion that has begun to set.

All mortar must be mixed and wetted in a proper vessel or on a tight flooring, and in no case upon the pavement or upon the ground.

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Following are some additional descriptions of material:

*Brick*, when broken should exhibit a uniform grain, free from air bubbles, cracks and coarse pebbles, and be capable of bearing a compressive strain when set on end and subjected to pressure of at least 1000 lbs. per square inch, before crushing, and should not absorb more than one-fifth of its weight of water.

No pale brick from the outside of the kiln should be admitted even for backing.

*Sand* should be rather coarse than fine, and whether pit or sea-sand, matters but little.

*Concrete.* The mortar as described in the foregoing specifications should be spread in a thin layer, and five volumes of broken stone, brick or shells after being washed of all dirt, *and while wet* should be spread over the mortar and turned and mixed thoroughly until each fragment of stone is enveloped in a layer of mortar. The concrete should then be deposited immediately in place in the work and rammed sufficiently to ensure that no vacuities are left in it, but that the mass is solid throughout. The broken stone should not be larger than will pass through a two and one-half inch ring.

*Timber* may be of pine, spruce, hemlock or other cheap timber if for shoring trenches, etc., and pine, oak or chesnut are suitable for foundation timbers.

### CONSTRUCTION OF SEWERS.

Pipe sewers should be laid on a two inch bed of sand, and the joints carefully filled with cement mortar.

Brick sewers sometimes require foundations of plank, timber, piles, concrete or a combination of these.

Tile drains are sometimes placed immediately below the sewers.

Invert Blocks should not be used, as, although they form an underdrain and are convenient to the workmen, they form a through joint, and ultimately, by the settlement of the sewer or otherwise a leak is formed.

The interior of the sewer should receive a coat of "neat cement," *i. e.*, cement without any sand mixed with it.

In cases where it is necessary to admit water to the sewer very soon after it has been laid, quick setting cement should be used; otherwise slow setting Portland is preferable.

One sewer should never enter another at right angles as such a construction causes eddies and cross-currents, and silt is deposited. The best method is to bend the tributary in by a tangent curve.

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## APPENDAGES TO SEWERS.

### MAN HOLES.

In the line of the sewers, both main and lateral, manholes should be constructed not more than 400 feet apart, and at every change of alignment, either horizontal or vertical. The object of the manhole is to furnish an opportunity for the proper inspection of the working of the sewer, for cleaning and flushing out obstructions, and also for ventilation. It is a brick shaft, elliptical at the bottom and tapering to a circle at the top, and fitted with an iron head over which is a perforated cover. A tin pan suspended below the cover will catch all dirt, etc., falling through the openings.

In flushing, a wooden disc or gate should be placed over the ends of the sewer in the manhole until sufficient water has been poured in to insure a sufficient rush to carry away obstructions. It is better to flush the lower end of the sewers and work upwards.

### STREET BASINS.

Street basins are placed at the intersection of streets and at other convenient places to receive the water from the gutter and convey it to the sewer. They should extend about two feet below the sewer into which they open. They should be trapped by a cast-iron hood or a trap-stone extending about six inches below the mouth of the sewer.

The object of the street basin is to arrest any solid matters which would otherwise be carried into the sewers.

### VENTILATION.

If abundant air be present when decomposition takes place, the gases seem to some extent to be deprived of their disease-creating properties, although the dilution with air after escape from the sewer does not seem to have the same effect.

The coverings in the manholes should be perforated for the passage of air; and if, as should be the case, the soil pipes of the houses are properly ventilated, no further precautions need be taken, as the sewer will naturally "breathe" by reason of the change of volume and temperature to which its contents are subjected.

When the outlet of a sewer is below water a ventilating shaft should be provided as near the outlet as possible, so that a current of air may sweep the sewer from end to end.

### HOUSE DRAINAGE.

Time does not allow of a discussion of this division, which is a subject in itself.

Such measures should be taken as will prevent the entrance of sewer gas under pressure and the siphoning of traps. The common forms of water traps are being abandoned in good work in the United States, and some form of mechanical trap used instead.

An excellent trap of this kind is the Bowers. In this trap a hollow rubber ball is firmly floated against the inlet pipe.

The advantages claimed for it are:—

1st. A perfect seal against sewer gas under pressure.

2nd. It cannot be siphoned.

3rd. Freezing does not injure it, as the hollow rubber ball yields to the expansion of the ice.

According to the old method of house drainage the soil pipe was led from the back part of the house, under the basement, to the street in front.

The modern arrangement is to have the lateral sewers traverse the alley to the rear of the house and to have the soil pipe to empty directly into it. The advantage of having the sewer in the alley is that it is more accessible than when in a paved street.

# SCALE CALCULUS.

By T. R. Rosebrugh, B.A.

Soon after the discovery of logarithms, Gunter invented what is known as Gunter's line, a scale on which divisions were engraved and numbered in such a way that the distance of each number from the origin (at which unity was placed) was proportional to the logarithm of the number. By means of a pair of dividers the logarithm of any number could be taken off and added to another logarithm on the scale, thus obtaining the product of any two numbers. If the distance given by the dividers were set off in the opposite direction, the difference of the logarithms, or the quotient of the two numbers, could be obtained. If the points of the dividers were set at any two numbers of the scale the distance thus obtained would be the logarithmic measure of the ratio of those two numbers, and by adding this distance to the logarithm of any number, the product of that number by the given ratio could be obtained.

In the sliding logarithmic rule sometimes used by engineers the pair of dividers is replaced by a second similarly graduated scale, sliding in a groove past the first and carrying its divisions along the same line.

In this scale multiplication or division by any ratio is effected by a relative displacement of the two scales. This displacement causes those numbers, whose logarithms differ by the amount of the displacement, to fall opposite to each other. Thus, to find numbers which are to one another in a given ratio, all that has to be done is to place the numerator of the ratio on the one scale opposite the denominator of the ratio on the other scale and all numbers which are then opposite each other are to one another in the given ratio.

As the divisions are of unequal length no vernier can be used and the reading of finer sub-divisions than those actually marked must be accomplished by direct estimation by eye, corresponding in function to the interpolation by differences in the use of tables. It may be seen that the accuracy of results thus obtained, with a scale which cannot conveniently be much more than two feet in length, is not very great; though for many practical purposes such scales are of great utility.

Before showing how greater accuracy may be obtained in practice, I shall explain the principles that must be introduced in order that triangles may be solved.

We may, for convenience, regard a plane triangle as consisting of seven variable elements, three angles, three sides, and the diameter of the circumscribing circle. To connect these we have the four equations:—

$$\frac{a}{\text{Sin}\,A} = \frac{b}{Sin\,B} = \frac{c}{Sin\,C} = \frac{d}{Sin\,90^\circ} \;\ldots\ldots\; (1),\ (2),\ (3).$$

$$A + B + C = 180^\circ \;\ldots\ldots\; (4).$$

With seven variables and four equations we require three more independent relations; these in general, are of the simplest form, and consist of the values of any three elements, with the exception of the three angles.

If we had a scale in which the sines of the angles were placed as the numbers are in the slide rule (at distances from the origin proportional to their logarithms) and if, instead of the sine we write the corresponding angle at each graduation mark, it may be seen from equations (1), (2), (3) that when the side $a$ is opposite the angle $A$ the other sides will be opposite the corresponding angles, the diameter of the circumscribing circle will be opposite the angle 90°, and the scale will express all that is mathematically contained in the first three equations. If the observer then attends to the fourth equation in addition to examining the scale, the solution of all triangles may be effected without calculation.

The most obvious method of increasing the accuracy of the scale is by increasing its length. We may then plot the logarithms on a larger scale, and also introduce the logarithms of larger numbers; thereby avoiding, to some extent, the interpolation of numbers by the eye.

It is not necessary that the scale should be on one straight line; it may be laid off along a helix or other curved line, or along a series of parallel lines. To lay off the scale along a series of parallel lines, equidistant parallel lines are drawn upon a sheet of paper or metal which is either flat or rolled upon a cylinder, in which case the lines are parallel to the axis of the cylinder. We may then imagine Gunter's line magnified to the required size and divided into as many equal sections as there are parallel lines; these sections are then laid off in succession on the parallel lines of the scale. In what follows I shall refer to this sheet as "the scale."

To multiply a number by any given ratio we may use a sheet of tracing linen, or other transparent substance, having equidistant parallel lines on which Gunter's line has been laid off in the same manner as on "the scale"—the distance between the lines and the graduation of the numbers being exactly the same in each. When, therefore, the transparent sheet, which we shall call "the ratio operator," is laid on "the scale" so that any number on the "ratio operator" coincides with the same number on "the scale," then every number on the "ratio operator" coincides with the corresponding number on "the scale."

Thus our "ratio operator" and "scale" are nothing more than a very long sliding logarithmic rule, cut up into sections for more convenient manipulation, and all operations which can be performed by means of the sliding rule, can be performed with increased accuracy by shifting the ratio operator on the scale.

Unless the scale is extended, a portion of the operator will fall outside the scale, and thus be rendered useless. Each section of the scale is therefore continued to the right, the continuation being an exact duplicate of the section immediately following. Thus, the continuation of the first section is a duplicate of the second, the continuation of the second section a duplicate of the third, and so on.

If the scale is rolled on a cylinder of exactly the same diameter, no other extension will be required, but in other cases it will be necessary to repeat the first portion of the scale, so that for every ratio the operator may be entirely within the scale.

On the operator the graduation marks are conveniently made below the line, and on the scale, above, so that the latter may be read through without interference.

The solution of triangles will be effected by means of another transparent sheet similar to the "ratio operator"; but, instead of Gunter's line, containing angles graduated at distances proportional to their logarithmic sines, this sheet, which may be conveniently called the "chord operator," is in reality a "ratio operator" on which, instead of numbers, we have the sines of angles.

When the "ratio operator" is laid on "the scale" in any given position, all numbers which are coincident are to each other in the same ratio. Therefore, when the "chord operator" is laid on "the scale" in any given position, the sines of the angles all bear the same ratio to the numbers on "the scale" with which they coincide. Now this is all that is mathematically contained in the equations (1), (2), (3); therefore, in the solution of triangles, the chord operator and scale may be substituted for those three equations.

[Mr. Rosebrugh then exhibited a scale and operators, which he had prepared on profile paper and tracing linen, and readily solved several problems in ratio and in the solution of triangles which were given him by members of the society. The method of solving problems in ratio has been already explained, but it may not be out of place to give in detail the method of solving triangles.

Having given $a$, $b$, *and* $A$.—Place the "chord operator" on "the scale" so that the angle $A$ coincides with the number $a$; then $B$ will be that angle which coincides with $b$. $C$ will be found from the equation $u\ C = 180° - A - B$, $c$ will be the number which coincides on the scale, with the angle $C$, and $d$ will be the number which coincides with the angle 90°.

Having given $a$, $b$, *and* $C$.—The sum of $A + B$ is known from the equation $A + B = 180° - C$. Shift the "chord operator" on "the scale" until the angles coincident with $a$ and $b$ have a sum equal to $180° - C$. Then the angle coincident with $a$ will be $A$, and that coincident with $b$ will be $B$. Without moving the operator, read off the number which coincides with the angle $C$, this gives the side $c$. The number which coincides with 90° gives $d$.

Having given $a$, $B$, *and* $C$.—$A$ is found from the equation $A = 180° - B - C$. Place the angle $A$ of the operator on the number $a$ on the scale. Then $b$ will be the number coinciding with the angle $B$, $c$ will be the number coinciding with the angle $C$, and $d$ the number coinciding with the angle 90°.

Having given $a$, $b$, *and* $c$.—Shift the "chord operator" on "the scale" until the angles which are coincident with $a$, $b$, and $c$, fulfil the relation $A + B + C = 180°$. Then the angle opposite $a$ will be $A$, that opposite $b$ will be $B$, that opposite $c$ will be $C$, and the number opposite 90° will be $d$.

Some of these solutions involve the method of trial and error, but with a little practice, the results may be obtained very rapidly, and accurate enough for any practical purpose.]

# MASONRY FOUNDATIONS.

By J. L. Morris, C. E.

From the primitive cedar post to the permanent solid rock we have so many various forms of foundations, that in a few years of practical experience an engineer can have encountered only a small fraction of the different modes of preparing the bases of structures. Yet for the ordinary local work of the civil engineer, the few practical hints which this paper may contain may be of some value and may pave the way for the more general adoption of better methods of construction.

The importance of the security of foundations should not be underestimated, for, whatever the superstructure may be, if the foundation is weak the whole structure partakes of that weakness; and very often we see fine structures ruined through want of knowledge or false economy in the construction of the foundation.

It is customary when preparing the foundations of buildings, to make certain of being below the level of deepest frost, but where the walls, as in the case of public buildings, are heavy, it is necessary to prepare a foundation depending upon the material upon which the structure stands. The different methods of constructing the foundation, which will be described further on, will be found suitable to all classes of building.

Rankine, in his Civil Engineering, treats of masonry foundations under three heads. (1) Foundations in rock, (2) Foundations in firm earth, (3) Foundations in soft earth. These include those foundations where an excavation alone is required, and where a structure is necessary at the bottom of the excavation to form a firm base for the masonry—which includes foundations, both natural and artificial.

It is often necessary to determine what our foundations are to be, before any work is commenced (especially where a close estimate is required, and tenders are called for) so as to give the contractors reliable information. This information is secured by means of the boring rod, which may be composed of an auger and rods for lengthening as the boring proceeds. The material brought up by the auger from time to time furnishes us with the information concerning the underlying strata. If we come upon rock, we must be satisfied that it is not a boulder by repeated borings, which will also give us the slope of the rock. Very often we find rock on the surface at one point and by taking borings at a few more points, determine what we think is its slope under the position of the whole structure, and when work commences, are surprised to find that where we had calculated for rock, there is none, either for the foundation of a pier or the end of some retaining wall. This is the cause of so many extras in foundations. When we have secured solid rock for a foundation, we find that it often presents a broken and irregular surface, with cracks and fissures, which before beginning construction, must be either levelled off by excavation of the rock, filled up to a level surface, or made with horizontal steps. The levelling may be done by blasting and working off the irregularities, filling of the fissures and cracks with concrete, made of one of cement, two of sand, and from two to four of broken stone, or by stepping the rock so as to leave only a solid bed, and no imperfect formation or shale. If the rock is of a good and hard quality we have here the nearest approach to a perfect foundation.

On land where no water is to be dealt with, the levelling or filling can be easily done; but where a coffer dam has to be used to shut out the water, and the fissures and cracks in the rock cannot be stopped up to prevent its entrance, so as to allow of levelling or stepping the rock, then we remove all debris and shale, and level the foundation with concrete enough to cover all irregularities in its surface. Boxes, for the purpose of placing concrete where there is a great depth of water, are used, so as to prevent the sand and cement from coming to the surface, the broken stone being left at the bottom. Without these boxes, should the concrete be thrown in carelessly, this is usually the case, but where there is only a few feet in depth, of water, and a large mass be thrown in at once, it reaches the bottom before the water permeates it and causes the rock, sand, and cement to separate. Whatever is done to secure a solid foundation, it must be understood, that a structure should never be built on sloping rock. Where no rock is to be found at any reasonable depth, then we bring into use our knowledge of artificial foundations. It may be possible for us to determine before excavation, by means of the boring rod, what manner of foundation we should construct; but certainty can only be arrived at by having our excavations made, and the materials upon which we are to work brought to view. Should we find that at a reasonable depth, we have come upon a layer of cemented earth or other very hard material, and we find by boring that it overlies a strata of much poorer material to resist pressure when disturbed, then if we are satisfied that the thickness of the bed is sufficient to sustain the pressure, we might save both material and labor by commencing our structure, but if we are not satisfied with it as a foundation, we fall back upon some one of our artificial constructions.

It is becoming customary for the heaviest of structures to be built on foundations made of concrete, thrown in upon the earth without any intervening material, the idea being that when it solidifies it takes the place of a rock foundation. This only gives security, when we have superior tested cements, allowed to set under very favourable conditions. Often broken and sometimes half bricks are used in the manufacture of concrete, but it is absurd to use a material of so much less resistance to compression than stone, when compression is the force against which we are contending.

There has come under my notice the foundation of a heavy abutment, being part of a stone bridge, with two piers and two abutments, with three segmental arches of a clear span of nearly fifty feet each, the archstones being three feet in depth. It was built upon a foundation composed of two feet in depth of concrete, upon a bed of blue clay. During the formation of the concrete it was subject to a continual wash of water, owing to the pumping to keep the inside of the coffer dam dry, thus drawing the cement from the concrete and leaving a mass of brick and sand. After being allowed to set for two days it was possible to force a half-inch iron rod through any part of it. I am satisfied, considering the strain on the concrete, that its strength lay in having the extremely hard material below it. All other parts of this bridge were started from the rock.

A more complete foundation, and which would distribute the pressure more evenly in case of any settlement, would be to place timbers 12 in. x 12 in., about eighteen inches apart, at right angles to the course of the stream, the space between to be filled up with con-concrete to their level. On top of this to have a platform of 8 in. x 10 in. material, spiked to the timbers below, allowing a footing of about 12 in. outside of all masonry. This is a permanent foundation, as timber submerged does not decay. On Lake Geneva, where some of the old Swiss towns were built, about two thousand years ago, piles have been found, as perfect as when first driven, for the basis of some structure, owing to their having been continually under water.

Should we find it impossible to secure hard material, as a basis for concrete or timber, we are compelled to resort to piling. This is more expensive than either of the other methods, but when properly carried out gives a surer foundation. Piles about 13 in. at the larger end and 8 in. at the smaller end, of tamarac in preference to any other soft wood, should be driven at from two to four feet centres, depending upon the weight of the structure, their length depending upon the material through which, and also to which, they are driven. If there is no underlying rock at a reasonable depth, then when the piles are driven so that the hammer (say two tons in weight, and falling a distance of twenty-five feet) at each blow would drive the pile about two or three inches, when it has gone a depth of about twenty feet, then we can rely upon having a good foundation; but any greater subsidence at each blow might leave a foundation which would settle under the pressure of the masonry. The piles are sawn off at the required height (always below low water when on the bank or in a stream) and may be prepared for masonry in either of the following ways: (1) By excavating three or four feet of material from between the piles, and filling in with concrete, making a solid mass of timber and concrete. (2) Using no concrete, but placing sills on top of each row of piles, and flooring with timber, the dimensions of which will depend upon the distance of the piles apart. (3) By combining the two previous modes.

The first has this fault, that in case of any settling it would be uneven, owing to the different materials, and would cause the masonry to crack. The stone abutments for a hundred feet iron truss bridge, over the Little Sturgeon River, Lake Nipissing, were built upon a foundation of this stamp, and owing to settlement, the front wall separated from the wings. Where abutments or piers have been built upon foundations of either the second or third kind, I have not known of any settlement with injury to the structure.

The wooden structures, first built when timber was cheap and stone never thought of, are being replaced generally by stone box culverts, many of which require special forms of foundation. The excavation for the foundation is made deep enough so that the top of the timber shall be below the level of the bed of the creek or watercourse. Four sills for the main body of the culvert shall be laid its full length, two under each wall of the body of the culvert, with three or four feet of projection at the lower end for an apron, to preserve the foundation from the wash of water discharged by it. Short sills, parallel to the sills under the main body, shall be placed for the wing walls. On the top of these sills and transverse to them and the centre line of the culvert are placed sided ties of either hemlock, cedar or tamarac, not less than six inches in thickness, and with not less than eight inches flatted face. These are made one foot longer than the total width of the culvert, so as to allow for a footing of six inches all around the masonry. As openings will be left between these ties owing to the sides not being hewed, they should be filled with spalls and the sediment brought in by the water, will, in time, form a natural bed for the flow. There can be no objection to the squared ties being used, as the flatted are used only for economy.

Near Sudbury, Ontario, a temporary trestle had been built over a water course, with a very small flow of water, and an opening left for a stone box culvert. When excavating for the foundation of this culvert, we came upon a bed of quicksand, and were unable to make any headway and were undermining the sills of the trestle. It was impossible to insert sills, so using squared timbers 12 in. x 12 in., and hammered close together, a foundation was made on top of the quicksand, and the water was discharged through the culvert about 1·8 inches above the bed of the watercourse at the lower end by means of a diversion.

These hints are only to pave the way for improvement ; but no matter what the structure is, be sure of your foundation.

# SURVEYING IN THE CITY AND SUBURBS OF TORONTO.

By D. D. James.

In this paper I will treat briefly the subject of land surveying as practised in the city and suburbs of Toronto.

I find it convenient to take up first a surveyor's work in the suburbs. The greater part of this consists in the preparing and staking out of plans of subdivisions.

Probably it would be better to give an explanation of a plan of subdivision. When the owner of a block of land wishes to sell his land in smaller portions he has one of these plans prepared by a surveyor. He then, having signed the plan, registers it, that is, takes it to the proper registry office and has it put on the file of plans. Now, in transferring lots shown on the plan, the statement of their numbers, together with the number of the registered plan, is the only description necessary in the deed.

If such a method of dividing up large portions of land were not available, it would be easy for complications to arise. Mistakes are more easily made when property is sold piece by piece, with no plan, than when a plan of the whole is prepared, to which reference is made in each deed. Besides, when a plan is registered, it is generally staked out by the surveyor, while, when the land is sold piece by piece, it is not generally staked out, but each man that buys will likely measure off what he thinks is included by his deed.

While speaking of registered plans, I may say to those unacquainted with conveyancing that any deed or plan in a registry office may be inspected and copied by anyone for a small fee.

### PRELIMINARY SURVEY FOR PLAN OF SUBDIVISION.

The information a surveyor needs before going out to make this survey is a copy of the deed of the property and a copy of the plan referred to in the deed. The latter may be the plan of the township, or some registered plan. If field notes relating to the property can be obtained they may prove valuable.

In the following discussion the word monument signifies either a stone monument or a wooden stake or hub.

In the preliminary survey the first thing to be done on the ground is to locate the limits of the property to be subdivided.

If monuments are found at all the corners of the property it is only necessary to check the measurements of the plan, to insure that the monuments are the ones sought for, and have not been moved since they were put down.

When monuments are not found on the boundaries of the property, but are found in the neighbourhood, the limits of the property are located by measuring from these neigbouring monuments. If there is a means of checking by fences and monuments it is taken advantage of.

If the measurement between two well-established points does not agree with the plan measurement the discrepancy must be divided up proportionally in establishing an intermediate point shown on the plan. If the intermediate point which is to be located is not a point shown on the plan, but a point given by the description in the deed, it must be located according to the wording of the description.

If monuments are not found, the surveyor must get evidence as to the positions of fences. The checking of the measurements between the fences, with the figures shown on the plan, is good evidence that the fences are in their correct positions.

In all cases where there are fences around the property over ten years old, the question of possession under the Statute of Limitations must be considered. On this account it is often not necessary to get up the lot lines. If, however, a large discrepancy, over which there might be litigation, is discovered, the lot lines must be located, and the difference between them and the fences must be noted.

As the Statute of Limitations does not apply in the case of road allowances, the road line cannot be assumed to coincide with the roadside fence, no matter how old it may be. On this account the original road line must always be located.

This case, where the Statute of Limitations comes in, is the one of usual occurrence.

The question of limits having been settled, a few measurements may be needed to determine the position of a house or barn, or it may be that a ravine or stream must be traversed, and the survey connected with the lot lines.

Here I may mention the instruments used by a city surveyor. They are a theodolite, or transit-theodolite, a Chesterman steel tape, and chain pins. Pickets are not often used, as they are clumsy to have in a street or railroad car. Split rails or boards are made on arriving at the property, and used in place of the ordinary pickets.

### PREPARING THE PLAN.

When the limits of the property have been plotted, the most profitable subdivision must be decided upon. The questions considered are these :—

1. How the most frontage can be made.

2. In what direction the lots shall be fronted in order to bring the highest price per foot.

3. How deep the lots shall be made.

4. How wide the streets shall be.

5. How wide the lanes (if any are to be opened out) shall be.

6. If the neighbouring property has been laid out into streets, how a continuous street can be economically made to run through both properties.

7. If the property cannot be laid out satisfactorily, how some arrangement can be made with either of the neighbours to give a part of a street.

8. If there are ravines on the property, how a street can be laid out so as to necessitate as little filling and cutting as possible, at the same time economizing the land.

It is seldom that all the above questions have to be considered in a single case. The best method of sub-division can generally be got at easily.

After the method of sub-division has been decided upon, and the plotting completed, the lengths and bearings of the new lot lines must be determined. If the limits of the property are crooked, or if the owner is in no hurry to get the plan registered, the property is staked out, and the unknown lengths and angles determined in the field.

When all the lines are straight, and the necessary angles have been measured in the preliminary survey, the unknown lengths and angles may be calculated.

It is not safe to calculate from the angles given by the bearings of the previous plan. The reason of this is that the bearings on the plans are calculated from the original township bearings, and these are often inconsistent with the angles, that the lines, to which the bearings belong, make with one another. On the new plan, these sometimes inconsistent bearings are again used for lines parallel to original lines. The new bearings are calculated from either of the old ones.

### REQUIREMENTS FOR REGISTRATION OF PLAN.

Before a plan can be registered, every line must have its length and bearing marked upon it, and the lot lines and numbers of the previous plan must be shown. The new sub-division must also be connected with the previous one, showing distinctly how much of the previous sub-division is covered by the new one.

The plan (generally finished on tracing linen) must have on it a certificate for the owner to sign, besides the prescribed surveyor's certificate.

### REMARKS ON PLANS.

The surveyor always keeps copies of the plans he prepares, and has some system of filing them in his office. One way is to fix the copies by their edges into a portfolio ; another way is to plot copies in a large book kept for the purpose. In these two methods the copies cannot be misplaced or lost, but they cannot be taken on a survey when required, so that a sketch of the portion needed must be made in the field book. Another method is that of making packages of the copies so that any one of them can be taken out on a survey when required. Here, however, the copies may be misplaced or lost.

Whatever the system of filing the copies, the indexing of them is very important. The method of indexing, which, I think, is the most simple, and at the same time the easiest to carry out, is that of having index maps. (Such a map as the one given with this paper would make a good index map.) This method will apply to all the information in the office, as copies of plans, field notes and descriptions. In this method the number, or letter, which indicates where the information is to be found in the office, is placed on the index map on the spot to which the information relates. When one seeks information about any portion of land, he always knows the exact locality, then a glance at the index map will enable him to find all the information in the office that bears on the subject.

Another point I wish to direct your attention to is that of reserving a foot of land along the boundary of the plan, where a lane or a street has been made to meet or follow it. This reservation does not allow the neighbouring owner to get an entrance to his property without paying for it.

### STAKING OUT THE PLAN.

After the method of sub-division has been decided upon, and perhaps the plan completed and registered, the location of each point of the plan is marked on the ground by a stake. The stakes are usually of pine 2 in. x 2 in. and 18 in. to 22 in. long. They are put in line by a theodolite or transit theodolite. When there is only one assistant, the proper places for the stakes, as regards measurement along the line, are previously marked by chain pins. When there are two assistants, one holds the tape at the last stake put down, while the other puts in another stake at the proper distance, being lined in at the same time by the man at the instrument.

Stakes in straight lines along a fence are put in by means of offset lines.

The stakes along the limits of the property are usually put in first, then the stakes on the straight lines inside the limits are put in by joining the proper stakes on the limits. In joining two points, where neither can be seen from the other, the instrument is often set up between and shifted into exact line by trials. The stakes are then put in as mentioned before. Any measurements that have been left undetermined are now determined in the staking out.

I will now take up the second part of my paper, a surveyor's work within the city limits. This consists mostly of the getting up of lot lines of old subdivisions for various purposes. If the lots are not built on, the object is generally to give a builder the lines up to which he may build. The owner may want the lot or lots re-subdivided, making each new lot such a width as to exactly include one of some proposed houses. The new subdivision lots are generally staked out, so that the contractor can put the party walls of the houses exactly in their proper places. When the lots, the lines of which are to be located, are built upon, one of the objects of locating the lines is to see that the houses and fences are situated in accordance with the descriptions in the deeds. Another object is to determine the positions of the houses and fences with reference to the lot lines, so that descriptions of the houses can be made or a plan of them prepared for registration.

### SURVEY TO LOCATE THE LOT LINES.

After gathering the information that may be of use, the surveyor, on arriving at the property, pokes and digs around for old stakes on the street line. The value of a stake depends upon its distance from the lot line to be located. If, on different sides of this lot line stakes are found, there is seldom trouble in determining where the lot line and street line intersect. When this has been done the other end of the lot line that is at the rear is sought for in a similar manner. Whether at the front or rear, if no stakes can be found, and no evidence can be gathered as to existing boundaries, the problem of locating the lot line may be called one of trial and error. An existing street corner which seems to be accurately placed, is measured from and the measurements to existing boundaries noted. The surveyor is then able to form an opinion as to the position of the street corner. Another trial measuring from some other point may be necessary. In this way the lot line may be determined. It is always important to the surveyor if he can get copies of field notes of previous surveys in the neighbourhood. He may have field notes of the kind in his own office, hence the importance of having a good index to all his information.

Having located the required lot corner, the distance of the centre line of a party wall between two houses, from it, is determined by producing the centre line by means of an offset line, or if the thickness of the wall is unknown, two offset lines may be used.

When the survey is finished, a plan, sketch, or description, as the case may be, is prepared.

The plan is prepared so that lots may be made with their lines agreeing with the party walls of houses already erected or to be erected. If the houses are erected, they are shown on the plan. In the case of the proposed houses the lot lines are merely shown, but when the houses have been built, the centre lines of their party walls are, after due survey, certified to be coincident with the lot lines of the plan. The preparation of a plan, otherwise, is similar to the preparation of a subdivision plan already spoken of.

A sketch is merely a copy of the field notes and so its preparation requires no explanation,

An example of a description that would be prepared in the case of a survey of houses is given here. It runs as follows :

All and singular that certain parcel or tract of land and premises, situate, lying, and being composed of part of lot eight, registered plan No. three hundred and ninety six (396), a subdivision of part of park lot No. twenty eight (28), in the City of Toronto, County of York, and Province of Ontario, and may be more particularly known and described as follows :

Commencing at the Northwest angle of lot eight, thence Southeasterly following the East limit of Gladstone avenue, twenty-one feet eight inches (21 ft. 8 in.) to the intersection with the production of the centre line of the party wall, between houses numbers fifty-five (55) and fifty-seven (57), thence following the production, centre line, fence, and partition between the sheds at the back of said houses, in all, one hundred and twenty-one feet four inches (121 ft. 4 in.) to a ten foot lane ; thence Northwesterly along the Eastern limit of said lane twenty-one feet ten inches to the face of a shed on lot nine, being at the Northeast angle of lot number eight ; thence Southwesterly following the North limit of lot eight and passing through a passage between houses numbers fifty-seven and fifty-nine, one hundred and twenty-one feet two inches (121 ft. 2 in.) to the point of commencement.

# CORRUGATIONS ON MILL ROLLERS.

By W. Leask.

In treating of this subject the writer will first give a brief description of how the rolls are made and prepared for corrugating, also a simple device used for corrugating rolls, and then compare the different styles of corrugations, stating some of the advantages and defects of each.

The shafts to be used in the rolls are cut from round bars of iron or steel, as the case may require. They should be of good quality, and of such size as not to bend under any unusual pressure that may be brought to bear upon them during the operation of grinding.

The roll bodies for flour mill rolls are at the present time mostly all of chilled cast iron, and are fastened to the shaft by being cast on to it.

Each shaft is centred and straightened on the lathe and then ground on the stone at the places where the molten iron is to adhere to it. The grinding removes any rust or scale that may be on the shaft in these places, and puts the surface in a better condition for receiving the hot iron and allowing it to form a close contact.

When the moulds for casting are ready each shaft is laid in its proper place in the mould. The mould is closed (*i. e.*, the halves are put together), melted iron is poured in, left to cool, and become fast to the shaft.

After the rolls are cleaned of the sand from the mould, with a steel wire brush or other means they are taken to the lathe, put in, and turned true at the surface and ends.

Journals and places for the gearing and pulleys are turned to the proper size and finished.

Porcelain rolls were at one time very extensively used in Europe, but there were also many smooth chilled iron rolls, perhaps more than porcelain, in use.

The porcelain was in the form of a cylindrical shell, and the mode of fastening it to the shaft was to key on the shaft a ribbed cast core half an inch smaller than the inner diameter of the shell, then fastening the latter to the cast core by pouring melted sulphur in between the roller shell and core. Now, when the boxes got hot and the shaft with the cast core expanded, the sulphur and porcelain did not expand, and consequently would burst. Another source of breakage was the loosening of the shell and the sulphur becoming broken by the constant jarring and trembling.

This mode was superseded by one in which the rolls were fastened merely by friction, and the air was allowed to circulate between the shaft and shell. Two faced-off flanges are keyed on the shaft, and the porcelain shell is put between them, and by means of three strong bolts the flanges are pulled together on the shell as much as the bolts will stand.

The surface of the porcelain roll is finely turned off by means of diamonds.

The condition of the roller surface has greater influence on the work than the speed of the rolls. The roll is made either smooth or grooved, and in the latter case the grooves can be either parallel to the roller shaft or put in the shape of very steep screw lines, both rolls having a right or left hand thread, so that the corrugations cross each other at the point of contact, effecting the shearing of the particles to be cut or reduced in size. The latter method has also the advantage of making the machine run more quietly and evenly.

The amount of spiral twist given the grooves should vary with the character of the material being broken. Soft grain takes more twist than hard, because it is more sticky, and more twist gives more shearing action, which frees the corrugations from the sticky matter.

The size, depth and width of the grooved rolls are determined by the work the rolls have to do, as coarsely grooved rolls cannot be used if the particles fed to the rolis are already fine.

Special machines built in the most recent and modern style and supplied with all the arrangements and conveniences for corrugating rolls are now in use where special attention is paid to the manufacture of rolls.

To describe one of these would be rather lengthy for this paper, but a brief description of a very simple device which can be used on any common iron planer, may serve to give an idea of how rolls can be corrugated.

It is not intended to be set forth as a rival to the more modern machine which is of course preferable where it can be had, but only as a simple, easily made, cheap and effective device within certain limits: a device which can be made by any manufacturer requiring one.

The construction is briefly as follows:—

The roll to be corrugated is supported by means of two standards of cast iron of the form of angle plates, bolted on the table of the planer. The roll is placed lengthwise in a horizontal position between them.

One of the supports has a centre pin passing through it at the top against which, one end of the shaft of the roll butts; the other is supplied with a bearing, in which one of the journals of the roll is placed and secured by a cap. The roll is thus held in position by means of the centre pin at one end and the bearing at the other.

The end of the roller shaft which projects towards the rear of the planer is connected to the end of a larger shaft which has a square groove running in a steep screw line on it. The spiral twist on the shaft produces a similar one on the roll as it is being cut.

This shaft is made to slide through a worm wheel, which is supported by means of two standards and a cross piece, connecting their upper ends. These are fastened to the sides of the planer bed, one on each side, behind the main standards of the planer.

On the hub of the worm wheel is a journal which works in a bearing in the cross piece connecting the upper ends of the standards. A short key is stationed in the bore of the worm-wheel and operates in the groove of the shaft as it slides through. The worm-wheel is of course kept from turning by means of the worm, until another groove is about to be cut in the roll. The grooves are cut one by one.

The shaft on which the worm is keyed is turned by a ratchet wheel and lever. The end of the lever drops on the rear end of the table and receives its due amount of stroke as the table moves backwards and forward.

Care must be taken to have the axis of the roll in line with the direction of the motion of the planer-table.

The cutting tool is sharpened and set according to the shape of the corrugation required.

In order to avoid much trouble in lining up again, when the supports for the rolls have been shifted, a shallow groove is made along the centre of the table and a projection to fit this grove is cut on the bottom of each support and set in it.

As to the style of the groove, the saw-tooth as represented in Fig. 1, seems to be a favorite for first break.

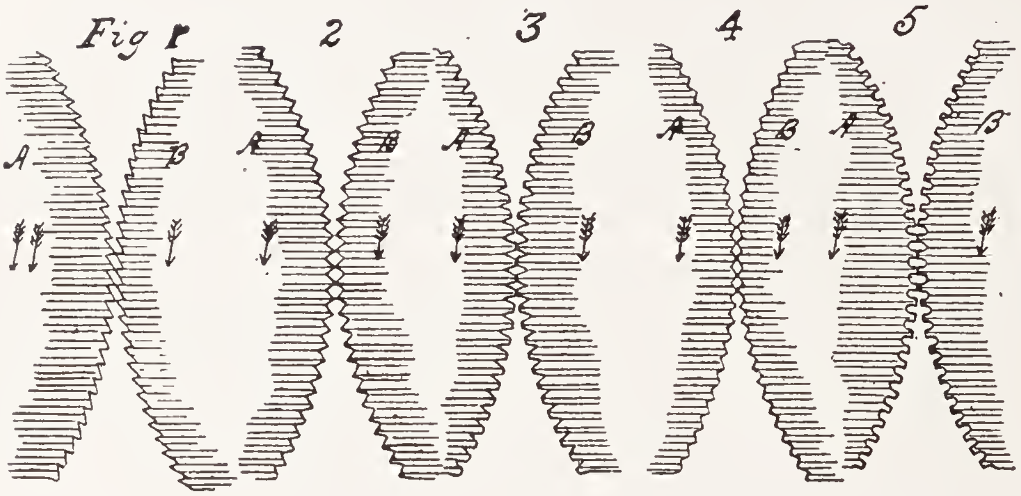
Fig. 2, represents the dress of the Sulzer rolls used about thirty-five years ago.

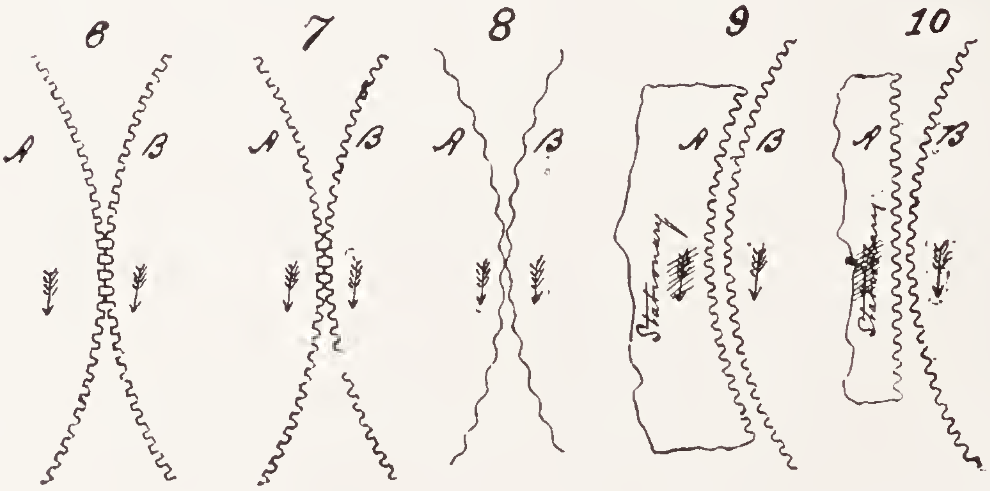
Fig. 3 is seldom used, its form is like Fig. 2 with its points turned off.

Fig. 4 is a very shallow corrugation, the space between the points is greater than the depth.

Figs. 5, 6, 7, represent corrugations that were used on very old rolls.

Fig. 8 shows round grooves but very shallow and wavelike.





Figs. 9, 10 show deep round grooves, but in Fig. 9 *B* is the roll and *A* is the stationary concave shoe. In Fig. 10, *B* is the ro and *A* a stationary straight shoe.

In the system of breaking wheat on corrugated rolls the aim of the miller is to reduce to middlings which are purifiable and to make as little flour as possible during the breaking process as it cannot be purified and will be mixed, more or less, with bran particles and dust having adhered to the wheat berry.

The dress, as shown in Fig. 1, gives the best results. Roll *A* is the fast roll and runs two or three times as fast as roll *B*. The wheat, if well graded, will be split open lengthwise almost every berry. Only a small quantity of flour is made in the first break, which flour is chiefly the dust lodging in the crease of the kernels, and therefore only fit to go into low grade flour. By the splitting of the berries a greater portion of the germ is got rid of.

If the ratio of the speed of the rolls be reduced the conditions are changed and more flour will be made owing to the increase of the squeezing action.

If the rolls be run at an even speed the conditions are entirely changed, as there will then be only a squeezing action.

Again, if *B* is made the fast roll and *A* the slow one the conditions are entirely changed as the work is then done on the back of one tooth passing the back of the other, producing a rubbing or bruising action which, of course, will again make more flour in the reduction which it is desired to avoid.

If *B* is the fast roll the pair of rolls must run about twice as fast to get capacity, and this, of course, means loss of power.

The corrugations as shown in Figs. 2, 3, 5, 6 are very apt to clog between the teeth, nevertheless they produce a good many middlings owing to the sharpness of the teeth.

The corrugations as shown in Figs. 7, 9, 10 are rounded corrugations which give trouble on account of their filling up soon and will do their work best on hard wheat.

Two rolls working together have been found, by experience, to give better results than rolls and shoes as the latter make too much flour and the shoes wear off very fast.

Dull rolls also require a great deal more power than the sharp rolls, as it has been experimented upon and found that it takes twice the power to squeeze wheat than it takes to cut it.

It is claimed then that the rolls corrugated as shown in Fig. 1 are capable of doing any kind of work that can be done with the sharp or dull rolls.

All depends upon what the operator desires to do if he understands the principle of the roller action.

For a higher percentage of middlings he may run the roll *A* fastest, for low grinding, more flour and fewer middlings he may run *B* fastest.

# A DESCRIPTION OF A TIMBER LIMIT SURVEY IN THE ROCKY MOUNTAINS.

By L. B. Stewart, D.T.S.

In the spring of 1884 I was engaged by an American lumber company to survey several timber limits in the Rocky Mountains; so I immediately set to work to make the necessary preparations.

I will first make a few general remarks with regard to the fitting out of a survey.

In fitting out a survey a considerable amount of judgment is required on the part of the surveyor in charge, in order that everything may work smoothly, and that the expenditure may be as small as possible, at the same time giving due consideration to the comfort of all composing the party.

The first point for consideration is the choice of a party. In this the surveyor must be careful to engage none but industrious and trustworthy men, and not to accept any man whom he knows to be worthless, as if he does he will have cause to regret it, and will probably receive small thanks from the man himself afterwards. There is no doubt that the members of a party must exercise a certain amount of fortitude in putting up with the little hardships that must necessarily occur even on the best planned surveys, and the man who always looks out for number one, or who grumbles at every possible opportunity, has no business to belong to a survey party.

In the purchase of provisions the surveyor must be guided by experience as to the amount of each article required. In the "Manual of Dominion Lands Surveys" is given a list of articles of food required on a survey, with the quantity of each required by one man for thirty days. This would be very useful in purchasing supplies.

Probably the point which requires most judgment is transport. The surveyor must obtain all the information he can with regard to the country in which the survey lies—such as the position of trails, rivers, etc.—and from such information he must decide upon the best means of transport. On the prairie carts may be used anywhere, drawn by Indian ponies. The improved Red River cart is the sort generally used, as they will stand any amount of knocking about. I have seen them roll sideways down a hill, turning over several times, without being materially damaged. The ponies are about as tough as the carts, as they never require any oats, and will find food for themselves on the prairies even in the depth of winter. A canoe or boat of some sort is also indispensable for crossing rivers which cannot be forded. The best kind is a canvas canoe made in sections so that it may be taken apart and packed for transportation. Sometimes the country to be surveyed lies on a large body of water ; in that case canoes may be used altogether for carrying baggage and for going to and returning from work. In the mountains the only mode of transport is by means of pack horses or mules, and a troublesome method it is, requiring a considerable degree of skill to tie on a pack so that it will stay there for hours if necessary. Great care must be taken to protect the horses' backs, to keep them from chafing; they should be examined every evening to guard against the first beginning of soreness.

Having finished my preparations, I set out with my party from Calgary with horses and carts, intending to travel in that way as far as possible. In a day or two we reached the mouth of the Kananaskis River, a tributary of the Bow, on which river the bulk of our work lay. We here stored the carts and what provisions we did not require immediately, together with all articles of baggage we could dispense with, as we were obliged to depend on pack horses in our future movements. We were now ready to begin work.

I had better here describe the system by which timber limits in that part of the country are surveyed. They are laid out in oblong blocks eight and one-third miles in length, by six miles in breadth, thus containing fifty square miles. Their length lies in the direction of the river on which they are situated, consequently they should extend a distance of three miles on each side of the river. The length, eight and one-third miles, is the length of an imaginary line joining the points where the two end boundaries intersect the river. The boundary at the upper end of each limit is run at right angles to this imaginary line which joins the ends of the limit. Thus in Fig 1.—which is purely imaginary, and must not be regarded as representing the true form of the limits—let us suppose that *a* is the point where the boundary of a limit already surveyed crosses the river, which is flowing in the direction of the arrows. It is necessary then to find a point *b*, distant eight and one-third miles in a straight line from *a*, *b* also being on the river, and to run the end boundary *cd* at right angles to *ab*, making *bc* and *ab* each three miles in length. There was a clause in the instructions which stated that the end boundaries need be run only as far as practicable, and I interpreted this to mean as far as was convenient, which was usually as far as the timber extended. They also stated that the side boundaries need not be run at all; it was quite unnecessary, if not impossible, to run these boundaries, as the precipitous ridges of the mountains already formed a much more permanent boundary than could be laid down by any artificial means. It was required, however, to make a careful survey of the river.

The method I followed was this:—I traversed the river in the ordinary way, and made this the basis of the whole survey; I reduced the bearings and lengths of the courses to latitudes and departures, and found from these the co-ordinates of each station, referred to a meridian line and an east and west line as axes, the starting point being the origin. I was thus enabled to find by a simple calculation the distance of any station from the starting point, and thus locate the two stations between which the end boundaries would cross. A short trigonometrical calculation then determined the precise position of that intersection and the bearing of the imaginary line above mentioned, and from this I found the bearing of the end boundary of the limit, which was run accordingly.

Thus the work of the survey consisted in making the traverse survey of the river and running the end boundaries, besides making the necessary calculations. This last was by no means the lightest part of the work, as on account of the extreme roughness of the country and the numerous bends of the river there were upwards of fifteen hundred courses to be reduced trigonometrically, and as I was not provided with one of Mr. Rosebrugh's computing scales, my spare time was pretty well occupied.

The only other point to which I will refer is the manner in which I made most of my linear measurements. I had had a little previous experience of mountain work, and that had taught me that a great deal of difficulty and delay is occasioned by depending on the chain alone for finding distances, and as I did not possess a micrometer, I resolved to resort to stadia measurements. I give a brief description of this method. In the first place, stadia hairs are two parallel horizontal hairs placed in the focus of the telescope of an instrument. If the telescope so provided be now directed to a graduated rod held so as to be perpendicular to the line of sight, the stadia hairs will appear to include between them a certain number of graduations, and that number is proportional to the distance of the rod from the outer focus of the objective of the telescope. The stadia hairs are first placed in the telescope and the rod graduated accordingly, by measuring carefully with a chain any convenient distance, say ten chains, plus the focal length of the objective, from the objective; an assistant then holds the rod to be graduated at the point so found, and marks according to your signals the points on the rod which are covered by the stadia hairs. This length is then divided into ten equal parts, which represent chains, and these may be further subdivided, and the whole rod then graduated in the same maner. To obtain the distance now between any two points, the instrument is set up at one point and the rod held at the other, and the number of graduations included between the stadia hairs read; this number added to the focal length of the objective and the distance from the objective to the vertical axis gives the distance in chains. This is the exact method, and to save the trouble of applying the correction to every reading I used an approximate method. The rod was first held at a distance of ten chains from the plumb line of the instrument, the points covered by the stadia hairs marked, and the distance between them divided into ten equal parts, and the whole rod then graduated as in the former method. The reading of the rod then gives its distance from the plumb line of the instrument exactly when that distance is ten chains, and the reading at any other distance is a very close approximation to the truth; the error certainly does not exceed the degree of inaccuracy of the method itself.

The advantages of this mode of obtaining distances are these:—(*a*) Quickness, combined with a considerable degree of accuracy; (*b*) inaccessible distances may be measured; (*c*) chainmen may be dispensed with. In my case, most of the courses lay along the channel of the river; I was thus able to obtain a clear sight, where otherwise it would have been necessary to clear lines through the woods along the bank, thus losing time and requiring a greater number of choppers in the party. I was thus enabled to reduce the number of my party to a minimum. The advantages above enumerated belong equally to any good micrometer.

The returns of the survey which had to be sent to the Department consisted of a plan, field notes, and report. The plan was required to show the lengths and bearings of all boundaries, whether surveyed or not, the area of each limit, and also any rivers or lakes included within the boundaries, together with the general topography. The field notes were to show the lengths of all lines surveyed and their bearings, and also the topography of the country passed through. A description by metes and bounds of each limit for insertion in the lease was also to accompany the returns.

On this survey we had the usual amount of hardship, in the way of exposure to all weathers, occasional short rations, and rough work generally, but I must say that there is nothing about surveying that need deter any man, possessing a moderate amount of manliness, from entering the profession. I have been out on many rough surveys, but I am always ready for another ; where the charm comes in I cannot tell, but it certainly does exist ; and I have had many a pleasant chat, " fighting the battle o'er again," with some companion of a past survey.

# TRACK LAYING.

By T. S. Russell.

In railroad building the amount of responsibility resting upon the various engineers employed, and the gain or loss to the company resulting from the manner in which they do their work, is about in proportion to the order in which their work is done.

First and foremost is the locating engineer whose duty it is to decide where the line shall be built, what shall be the average of the curves and grades adopted and similar questions, and the future success or failure of the whole road is greatly affected by, and in some cases altogether depends upon the wisdom of his choice. When these questions are decided and the line located, the constructing engineer comes on the field. The problem with which he has to deal usually is—how to build the best possible road for the least possible amount of money, and many and varied are the questions he is called upon to decide—questions which affect very considerably both the first cost of construction, and the subsequent cost of maintenance. Third in order, and I suppose third in importance, comes the track laying and ballasting engineer. His field is more limited. The line has been chosen for him by his first predecessor—and built for him by the second—and yet his office is by no means an unimportant one, and upon the thoroughness and attention to detail, with which his work is done, depend the speed with which trains may be run—and the safety and comfort of the passengers.

The work of track laying is usually done by contract, and ballasting by the railway company,—though there is no universal custom in these matters. The following extracts from track laying specifications will show the general requirements for good work.

## SPECIFICATIONS.

Delivery of Materials.—All material for track and switches, and plank for road crossings will be supplied by the company, and delivered to contractors on board cars at end of track—and after such delivery they will be considered as being in his custody, and he will be responsible for their safe keeping.

Preparing Roadbed.—All humps and hollows in the surface of sub-grade must be levelled off before ties are distributed. The approaches to all bridges and culverts must be filled in solidly and to the proper grade.

Track Laying.—The track to be laid on the finished sub-grade with square joints or otherwise, as may be ordered by the engineer in charge.

Ties.—Ties will number not less than 2,640 per mile, and be uniformly spaced between the joint ties. Joint ties will be spaced 10 inches apart between bearing surfaces. Large and well made ties must be picked for joint and shoulder ties.

Adze Ties.—Ties must be adzed when necessary to obtain uniform surface for rails, no notching allowed.

Lining Ties.—Ties will be laid truly at right angles to the track, and their south ends lined parallel to the rails—any ties knocked out of line by the rails must be carefully re-lined before spiking.

Switch Ties.—Switch ties and frog timber must be laid in accordance with standard drawings for the same.

Rails.—The rails if bent in handling must be perfectly straight before being laid in the track. Lay rails with maker's brand on outside.

On Curves.—On curves, when the inner rails overrun the outer by 2½ inches, a cut of 5 inches to be made, and a new hole to be drilled for the bolt in the proper place.

Bolts.—Every joint must have its full complement of four bolts.

Gauge.—The gauge will be 4 feet 8½ inches *exactly* on straight track, and on all curves of three degrees and under. For curves of four degrees, widen gauge (⅛in.) one-eighth inch, for five degrees widen gauge (¼in.) one-quarter inch, for six degrees widen (⅜in.) three-eighths of an inch.

Spiking.—Use four spikes to each tie, driven with proper amount of "stagger" to avoid splitting ties, and the two inside spikes to be driven in the same edge of the tie so as to keep ties at right angles to the track. Spikes to be driven as nearly perpendicularly as possible, snug up to the base of the rail, and no blow must be struck after the head of the spike is firmly driven down on the rail base.

EXPANSION.—Expansion and contraction of rails will be provided for by the use of the following rules:—In coldest weather use iron wedges $\frac{3}{8}$ in. thick, at freezing point use $\frac{1}{4}$ in. wedges, and at 70° F use $\frac{1}{8}$ in. wedges. This rule must be carefully observed, and the use of iron wedges is imperatively insisted upon, and the contractor must provide himself with a sufficient number of them of the thickness above specified.

ROAD AND FARM CROSSINGS.—Road and farm crossings must be put in wherever required, the inside planks will be placed $2\frac{1}{2}$ inches from rail to allow flange room, the outside planks will be placed as close as possible to the rails. No spike to be driven through the planks; track spikes will be used for fastening plank down, but they must be driven alongside of plank with the hook over edge, in the same manner as rails are spiked.

SIDINGS.—Sidings must be laid wherever required by the engineer in charge, and great care must be taken in laying switches to get them in exact accordance with standard drawings. Rails on leads must be curved to proper ordinates.

FINAL.—The track to be levelled up and well lined so as to be safe for the passage of trains at a reasonable rate of speed in transporting construction material, and ties must be so firmly tamped to a good level that there shall be no chance of straining or bending the rails. Materials for any tamping must not be taken from the shoulders of dumps, or from berms, nor from the side slopes in cuts in such a way as to disfigure them, but all such material must be taken from the ditches. The contractor must keep all newly made track in good line and surface while the work is in progress.

The price for track laying to be so much per mile for single track, and must cover unloading from cars, handling and delivering of all material to such points as it may be required for use—the laying of all switches for side tracks, laying planks for road crossings, and lining and necessary surfacing of track, and the completion of everything in accordance with the specifications and to the satisfaction of the said engineer in charge.

I shall say little about the cost of track laying. It is variable for different localities, and different states of the iron and labor markets, but can always be estimated fairly closely; much more closely than the cost of any other department of railway work. The quantities of material required can be calculated almost exactly, and having given their cost, the variable part of the whole cost becomes (1) the transportation of these materials and (2) the labor required in handling them and laying them in the roadway. The railway company usually supplies all material, transports it to the end of track and provides an engine and train of cars for use in the operation of track laying. The contractor receives the material from the cars and lays it on the roadway, putting in all necessary sidings, crossings, etc. The cost of this work depends on the price of labor, and on the organization of the track laying gang. The contractor must exercise all his skill and judgment to keep things working smoothly and quickly, and above all to avoid delays in any part of the work, for in track laying if any one part of the work is stopped, the delay extends to all parts and to all employed.

An important part of the engineer's work, also, is keeping up a constant supply of material. He has to estimate ahead the amount of material required for each day's work, and order all these supplies day by day from the officials in charge of the stores department.

The routine is about as follows: As the track is laid, the supply train is pushed on, and the cars containing the rails, ties, etc., are seldom more than a few hundred yards distant from the point where the material is wanted. The ties are hauled ahead with teams and distributed over the roadway. Sometimes this work is done at night, but this is impossible when a great length of track is laid in a day, as it necessitates a very long haul from some fixed point—the end of the track for the previous day. Following the tie distributors is a gang of men who straighten the ties out, lay them at right angles to the track, space them properly and line them on one side. This is done by stretching a rope along the sub-grade between stakes driven opposite the centre stakes and distant from them half the length of a tie, or usually four feet, and lining the ends of the ties even with this rope. Then comes the iron gang who run the rails forward on a small car or lorry as it is called, drop them on the ties and set them roughly to gauge. Then come the bolters who fasten the rails together by fish plates or angle bars and bolts, and lastly the spikers who guage the track and spike the rails down.

For the manner in which the work is done, the engineer in charge is responsible. He must inspect the materials and throw out any that he does not consider fit for use. The details of the work must be carefully looked after, and if any bad or carelessly done work is detected, he should insist on its being done over again, especially at the first. A great deal of trouble can be saved if the engineer strictly enforces the terms agreed upon at the start. He should train up the contractors in the way they should go, and as the work goes on they will not depart from it, if he still watches them closely. A great deal is left to the judgment of the engineer, and he must distinguish between clauses in the contract which being of very great importance must be strictly enforced, and others which do not affect the safety or durability of the road, which he may in some cases suspend. For instance in the above quoted specifications, the clause referring to the rails being laid with the maker's brand on the outside, may, under some circumstances be disregarded or set aside by the engineer, as the contractor might be unable to lay all the rails in this manner without great additional cost and delay in handling, and as this is a matter which concerns the appearance of the track only, and does not effect its usefulness. But in all details such as spiking, bolting, allowing a proper space between the rail ends for expansion or contraction, etc., details which go to to make up the difference between a good track and a bad one, the specifications must be strictly enforced. Perhaps no part of the work requires such close and constant attention as the spiking and guaging. The rail on the side on which the ties are lined should be spiked first, and should be made parallel to the line of the ends of these ties, at a distance of about one foot and six inches from these ends; the opposite rail should be guaged from this one. The ties must be truly at right angles before the rails are spiked on to them, and in all cases the spikes must be driven so as to prevent the tie from swinging sideways. This result can be obtained by insisting on the adoption of a universal rule, that the outside spikes shall be driven near the forward side of the tie, that is near the north side, if the line is being built in a northerly direction, and the inside spikes near the south side of the tie, or *vice versa*. Before the ties are distributed on the roadway, the engineer should run in the centres, making a line by stakes 200 feet apart on tangents and 100 feet apart on curves. He will obtain from the head office, or from the engineer who preceded him, a copy of the alignment notes containing information as to the position of the *BC's*, *EC's* and apex points, and of the hubs by which these points are referenced, also notes of the curvature and length of curves. Very often he will find that his curves will not fit at first, that is that though he starts a curve from the original *BC* it will end at the *EC* on a tangent parallel with the original one at some distance from it. The various hand books for engineers give formulæ to be used in such cases, by which he can calculate the distance necessary to move his *BC* back or forward, so that starting his curve from this new point, it will fit on the old tangent.

In laying track over bridges and culverts the centres must be carefully marked on the ties, (when these are spiked down, or otherwise secured on the stringers so that there is no movement) at intervals of not more than 15 or 20 feet by driving tacks in these ties. And it is also wise to offset at these points at right angles to the line, the distance from the centre to the inside of the flange of the rail, 2 feet 3 inches or 2 feet 3¼ inches according to the size of the rail, and make with a chalk line a continuous line across the bridge at this distance from the centres; the inside of the flange of the rail can then be placed exactly even with this chalk line, and spiked down, and the opposite rail gauged from it.

The centre lines for all sidings should be marked out by stakes, and the points at which the head blocks and point blocks for switches are to be placed should be similarly marked.

In laying out ordinary turnout curves there is no necessity for using a transit and the work can be done much more quickly by measuring with a tape line, previously calculated offsets from the main line. The width beween tracks will of course be fixed by the grading; 15 feet centres is a good width for passing sidings. The radius of the turnout curve will be fixed by the number of the frog used, and for the sake of symmetry, the same radius may be used for the reverse curve which brings the siding parallel to the main line. The curves may be made to reverse at one point, or they may have a short length of tangent between them—in either case the lengths of the offsets can be easily calculated by using a table of offsets from tangent for a 1° curve.

The first thing is to choose a point for the head block. This will usually be marked on the plan, but in ordinary cases, unless there is some special reason for doing so, it is not wise to cut a rail in order to make the switch begin at a fixed point. The rails are as a rule 30 feet long, and in ordinary practice it will do well enough to make the switch curve at the joint nearest the point marked on the plan. The distance of the point of frog from the head block will depend on the number of the frog used, or in other words on the frog angle. The lead rail should be carefully curved to points which are marked on the ties—these points being fixed by ordinates, and in laying off these ordinates, as in all calculations made for turnouts, it should be remembered that the curve does not begin at the switch, but at the point between the slide rails where they begin to bend, the distance of this point from the switch depending on the frog number and on the throw of the switch. A table giving all these dimensions with the radius of turnout curves, etc., for each frog number in general use will be found in Troutwine's Engineers' Pocket Book. In cutting rails for turnouts the lengths should, if possible, be so arranged that no material will be wasted and no more rails cut than necessary, thus for a number 9 frog, with 30 and 28 ft. rails and frog 10 ft. long, arrangement shown in Fig. 5 can be used.

Here only two 30 ft. rails are cut (except the short piece cut from the lead rail), and all the pieces of these two rails are used, also the joints become opposite to each other after leaving the frog, thus making the tracks symmetrical.

The base of the guard rail is notched to allow it to be spiked down, and at the same time placed opposite the point of frog with its flange touching the flange of the main line rail, thus leaving a space of about two inches for the passage of the wheel flange. Guard rails are about 14 feet long and at their ends are curved outward so as to leave a clear space of at least five inches between their ends and the main line rails. They should be firmly spiked down and also supported by braces or blocks on the inside, as they have to sustain heavy pressures. It is impossible to give many details of switches.

Standard plans are usually supplied for the guidance of engineers in building them, and these plans should be closely followed. Every part of a new switch should be thoroughly examined both immediately after it is put in and after it has been run over for some time. There is a great danger of new switches becoming foul, that is of the ends of the fixed rails on the head block not lying exactly opposite or in the same line with the ends of the slide rails. To prevent accidents the ties should be surfaced or tamped with earth soon after laying.

Rail joints are either square or broken. Square joints are simply joints opposite to each other, broken joints are those not opposite, the joint in one rail being usually opposite the centre of the opposite rail. The square joint is the one most commonly made. A joint is either suspended between two ties or supported by one tie. The former joint is the one most commonly used.

Many different kinds of angle bars and fish plates are used for making the fastenings. The work they are required to do is (1st) to keep the rails exactly in line with each other and to bind them firmly together, and (2nd) to act as bridge between the two joint-ties and thus support the ends of the rails. They are fastened together with four $\frac{3}{4}$ inch bolts which are supplied with washers and nuts. The nuts should be made very tight as the whole usefulness of the angle bars depend on the pressure they exert on the rail, which pressure is caused by the tightening of the nuts on the bolts. The holes in the rail through which the bolts pass are elliptical, allowing a movement of the bolt in the direction of the length of the rail of about $\frac{1}{3}$ of an inch or $\frac{2}{3}$ of an inch at each joint. Thus the rails can expand or contract without exerting any shearing force on the bolts. A 30 foot rail will vary nearly $\frac{1}{2}$ inch in length between the extremes of summer and winter temperatures, hence the necessity for regulating carefully the space allowed for contraction and expansion. The best way of doing this is by the use of wedges as provided for in the above specifications. There is also a tendency, more or less marked, of the rails to creep bodily in a certain direction—as down a heavy grade or in the direction of the heaviest traffic. This tendency may to a large extent be counteracted by driving the spikes in the joint-ties through the notches in the angle bars which are provided for this purpose.

When square joints are made they should be kept exactly opposite to each other. Sometimes one joint will get a little ahead of the other; in such cases, by using a wedge on one side a little thicker than that on the other, the joints can gradually be brought opposite. This method can only be used when the distance of one joint ahead of the other is small. On curves it is necessary at certain intervals to cut the inside rail in order to keep the joints square.

Five inches, the distance between the two holes in the rail, is a convenient length to cut off, as it necessitates the drilling of only one new hole. The total length of rail required to be cut from the inside rail of any given curve can be calculated as follows:

$g$ = gauge expressed in feet and decimals of a foot.
$r$ = radius of the inside rail.

$\frac{2\pi(r+g)-2\pi r}{360}$ = the difference in length between the inside and the outside rails for each degree of curvature. This reduces to $\frac{2\pi g}{360}$ which gives the constant ·08552 of a foot, being the difference in length of the inside and outside rails for each degree of curvature, therefore to find the total length to be cut from the inside rail on any curve we multiply this constant (·08552) by the number of degrees in the central angle of the curves (the minutes being either disregarded or reduced to decimals) and the product gives this length in feet and decimals. By bringing this to inches and dividing by five we have the number of rails which we must cut if the cut from each is five inches,—and a simple calculation gives the order in which these cut rails should come —that is the number of full length rails to be left between the cut rails, so as to distribute the unevenness of the joints as much as possible. It will be noted that the difference in length of the outside and inside rails is altogether independent of the radius of the curve used—the central angle remaining constant.

In conclusion an engineer is never too old to learn, and he must remember that in track laying—while he can get little information from his mathematical theories and not much from books regarding the details of the work—he can obtain a great deal from old railroad men —section foremen for instance. He must be constantly on the lookout for information and must never lose an opportunity of increasing his store of practical knowledge.

# PRESIDENT'S ADDRESS.

GENTLEMEN :

It is my privilege this afternoon to thank you for the honor you have done me in electing me to the presidency of your society for the ensuing year, an honor which I esteem all the more highly, for the cordial and unanimous manner in which it was conferred upon me.

In accepting this important office I have, I believe, a due sense of the difficulties of the position and of my own unaided inability to surmount those difficulties Fortunately, however, for me, and for the society, you have chosen a very prudent and energetic executive committee to guide and assist me ; and relying on their wisdom in finding out what it is necessary for us to do, and on their activity in doing it, I look forward with every confidence to a very prosperous year for the society.

You may, perhaps, in going through the woods, have noticed that it is much easier to follow a slow walker than a fast one. In like manner I shall find it more difficult to fill this chair acceptably, on account of the ability and energy of my predecessors. To maintain the society in the high state of efficiency in which they left it will be a difficult task—an almost hopeless task, did I not rely on the generous assistance of not only the executive committee but also of each individual member.

The society, as most of you are aware, was formed in 1885, and though the number of members was then small they were fortunate enough to secure the active assistance of Prof. Galbraith as president. In that capacity he watched over the interests of the society, encouraging and directing the efforts of the students until the end of the session of '87-'88, when, feeling that the society was firmly established, and that we were sufficiently numerous to undertake the management ourselves, he retired from the chair and advised us to elect a president from our own number.

The gentleman chosen, Mr. H. E. T. Haultain was in every way eminently qualified to undertake the work, and in addition to the great ability of the president, every member felt that peculiar stimulus occasioned by the knowledge that they were now considered strong enough to conduct the society themselves.

This year such a stimulus is wanting. Our position has lost the charm of novelty, and we must look to other means for keeping alive the interest in the society.

I had intended, in this address, to call your attention to the confusion of ideas which often exists in the minds of engineers owing to a defective terminology, and to impress upon you the necessity of having a very clear conception of what every engineering term should mean, and of never using it except to convey the proper meaning. But everything around us is in such a state of rapid transition, the number of students increasing so rapidly, and so much attention is being given to the new conditions of student life, which the ever increasing number of students necessarily entails, that I have decided to speak only of the Engineering Society, of our relation to it, and of our relation to one another.

All around us we see indications of rapid progress. Across the ravine is a beautiful stone edifice, built specially for a department of science which once found ample accommodation in these small rooms. We are daily expecting to see the excavations begun for a new gymnasium building and we ourselves have our meditations disturbed by the noise of workmen busy at a new School of Practical Science in relation to which the present building will be quite insignificant.

Nor are these buildings being erected before they are necessary. Nothing but the most uncomfortable overcrowding has forced the authorities to move. The number of students here, as well as at the university, is steadily and rapidly increasing. There are already ten students in the newly established department of Mechanical Engineering and it is expected that as soon as the new building is equipped the Mechanical Engineers will equal, if not exceed, the number taking Civil Engineering.

And, what is more important for us to consider just now, the changes in the social life of the students are equally as rapid and as far-reaching in their effects.

We see new societies springing up on every side—year societies, class societies, hazing and non-hazing societies and various other kinds of societies, until we are tempted to exclaim "Of the making of societies is there no end?" It is said that the tendency of the present age is towards combination and co-operation and truly the tendency of our college life is towards the formation of societies. In the midst of all this luxuriant growth of societies is the Engineering Society to remain stationary? Are we to rest satisfied with doing what our predecessors have done? Decidedly not. To remain unprogressive, to be satisfied with doing the same things which were done last year or the year before last—is to be smothered by the rapid growth of everything around us—to dwindle away and die. In order to maintain a healthy life we must develop at least as rapidly as our environment. We cannot rest on our oars if we wish to maintain our place in the front rank of the student societies. We cannot live on the laurels won by our predecessors, our own unceasing labour is the manna of our existence.

And why should we not do more than our predecessors? Everything they have accomplished is ours; we have but to start where they left off and build on layer by layer, beautiful and permanent as a coral reef in a Southern sea. How shall we accomplish this? How shall we make the society do a greater work than it has ever done before? Simply by well directed, unremitting, united effort.

One of the dangers which this extraordinary development of student societies may bring in its train is the idea of a federation or union of all the societies. We should avoid any such expedient. It might galvanize some life into some of the more defunct societies, but it would only retard our progress and endanger our safety. It is like tying the boats of a flotilla together, the better to stand the storm; it may appear safer for the frailer crafts but it is really more dangerous for all. I believe that some arrangement should be made so that our meetings would not interfere with those of any other society, and when programmes could be arranged suitable for two or more societies, joint meetings might be held; but any closer union seems to me inadvisable. Instead of endeavouring to make our society play a more prominent part in college politics and exert a more direct influence on the other societies, let us see to it, that it continually exerts a more beneficial influence on ourselves.

The constitution states that the objects of our society shall be "(1) the encouragement of original research in the Science of Engineering, (2) the preservation of the results of such research, (3) the dissemination of these results among its members and (4) the cultivation of a spirit of mutual assistance among the members in the practice of the profession of Engineering."

These few sentences express very clearly the work which it is hoped the society will accomplish, and they cannot be too strongly impressed upon the minds of the students. But what seems to me the grand and lasting result of all student societies is the reflex action of the society upon the minds of the students themselves. Were I asked to define the great object of this society I should say: "It is to afford facilities for, and to encourage, the development in the minds of its members of habits of reading and observation, and the cultivation of the ability to communicate information thus received by means of writing and speaking."

The great object for which we should attend college is not to make new discoveries in the field of science, it is not even to learn the truths which have been discovered, but it is for the training which our minds receive in mingling with other minds in the pursuit of knowledge, and in learning a little of what the master minds of this and other generations have accomplished. And when we leave here to practise our profession, if we are better men than those who have not attended here, it is not because we have done more, nor because we know more, but because our minds are better trained and we are therefore capable of knowing and doing more.

In this training of the mind the faculty have felt that the society was doing a useful work upon the lines which I have just indicated—a work which could not be so well accomplished by the ordinary course of lectures. They have therefore set apart two of the regular lecture hours for us to hold our meetings and I hope you will all realize that it is as much your duty to attend these meetings as it is to attend any other lectures in the school.

But I fancy I hear some one saying "I have attended a meeting of the society now and again, and tried to listen to some dry old paper and it never did me any good. This thing of deriving benefit from the society is all a humbug." My friend (if there is anyone here who has held this opinion) I quite agree with you. I would even go farther. Your attendance at the society has probably done you harm. The society *is* a humbug to you. But why? Thackeray has said "The world is a looking-glass and gives back to every man the reflection of his own face. Frown at it and it will in turn look sourly upon you; laugh at it and with it, and it is a jolly kind companion." If you wish to draw money from a bank, you must first put money in; if you wish to derive benefit from the society you must first become useful to it.

"All who joy would win
Must share it;
Happiness was born a twin."

This reflex action of a student's society upon the minds of its members is no new idea. All men unite in saying that in whatever degree they took an interest in the proceedings of their society in the same degree were their minds benefited thereby. Newton's Third

Law of Motion, that the reaction is equal and opposite to the action is as true in the case of our relation to a society, as it is in the impact of two perfectly elastic spheres. For the sake of the society, then, and for your own sakes, let me urge upon you the necessity of taking an active interest in the society, and if at all possible of contributing to the programme of at least one meeting during the year.

In order to afford better facilities for varied reading on Engineering subjects, the society has, during the past year, fitted up a small room where all books and papers, the property of the society, are kept. I very much regret that the students have not all availed themselves of this library in the way in which they might. There will be found there, the current numbers of the best Engineering Journals, besides several works on subjects connected with our course—the property of the old School of Technology. Any member of the society may take out these books and papers and read them at his leisure as long as he conforms to the library rules. There is nothing to hinder any student from reading, at least, one number of a periodical each week, in the spare moments when he does not feel like pursuing his regular work. He would thus, by selecting which ever magazine he prefers, and reading it continuously, be able to form a good idea of what is going on in the Engineering World around him. He would moreover find it a pleasant recreation from his severer studies, and above all, he would acquire broader views and develop a habit of reading which would be of inestimable value to him in after life.

But while laying great stress on the benefits to be derived from our library, we must not forget that the most important part of our work is the reading and discussion of papers. In fact, one of the greatest benefits of the library is that it stimulates and facilitates the production of papers. Reading and writing go hand in hand. Reading is the strongest incentive to writing, and writing is the truest test of correct reading. We have never really mastered a subject until we can write intelligently about it.

It is not my intention to suggest subjects for papers; in our work there is such an infinite variety of interesting subjects that it would take more time than is allotted to me even to name them over. But of one thing you may be certain—the subject in which you yourself feel most deeply interested is the one upon which you will most probably be able to write the best and most interesting paper.

With regard to the length of the paper so much depends upon the nature of the subject that no definite rule can be laid down. But I think it is generally agreed that short papers are better than long ones for two reasons :—The interest of the hearers does not flag and the short papers do not, as a rule, demand so much time for preparation.

However, it is not to the subject matter nor to the length of the paper—a good paper is rarely too long—but it is to the style of the paper that I desire to direct your attention.

Do not make your paper too comprehensive. Do not endeavour to compile an Encyclopedia of Engineering which can be read in fifteen minutes—for you can't do it. First form a perfectly clear and definite conception of what your subject is, and then write about nothing else. "Scattering shot may hit many things, but it never brings down big game." There is a society in the neighbouring republic where every paper read is the embodiment of but one thought. To write a paper of that description is, no doubt, beyond our powers, but such is the ideal which we should strive to realize.

By confining ourselves closely to our subject we shall more easily avoid another danger which I wish to mention—the tendency to make our papers too condensed. No paper which is merely a catalogue of dry facts can excite any human interest. Do not attempt to crowd too much information into a given space ; such a course necessitates paring down our sentences to the smallest possible size, stripping them of all ornamentation and even twisting them out of shape in order to squeeze them in. Remember, our thoughts must be clothed in words—and clothed properly. As a man never looks well if his clothes are too small or unsuited to his work, so thought loses half its dignity when not expressed in appropriate language. As with clothing the language should not be so inferior as to bring the thought into contempt, nor yet so florid and ostentatious as to divert our attention from the ideas by compelling us to contemplate the verbiage.

What we want here is not a great deal of information in uninviting form, but a few facts in a shape in which they may be easily assimilated—information in a pleasant palatable condition, sugarcoated with humour and flavoured with wit. In fact, what we should deal in here might be appropriately called the bon-bons and sweetmeats of engineering science. I maintain that that knowledge which is associated with pleasant recollections is the most easily acquired and the most permanently retained, and I cannot understand why wit and humour are excluded from philosophic works as having no part therein. They seem to me like rays of sunshine gleaming through the forest leaves of scientific thought, cheering the student on his lonely way. I am inclined to think that the number of profound mathematicians would be greatly increased were the Conic Sections or the Calculus interleaved with selections from Pickwick or clippings from a comic newspaper. But I hear some one say "That would be beneath the dignity of the subject." Perhaps it would. Yet we must remember that dignity does not consist in being serious and matter-of-fact, any more than in being cheerful and good-humoured. Even in mathematics there are opportunities for giving many sentences a humorous turn, and if mathematicians took advantage of these opportunities, their books would be much more interesting and, therefore, more instructive.

We should always remember what Sir John Lubbock says in his exquisite work, "The Pleasures of Life": "It is not without reason that everyone resents the imputation of being unable to see a joke. Laughter appears to be the special prerogative of man. The higher animals present us with proof of evident, if not highly developed, reasoning power, but it is more than doubtful whether they are capable of appreciating a joke." And that even Carlyle has said: "No man who has once heartily and wholly laughed can be altogether irreclaimably bad."

Finally, gentlemen, do not be original. I mean, do not strive after originality. It should not be expected of you. We do not ask a builder to put on the roof before the walls are raised, nor do we expect Stanley to make discoveries in Africa before he has ascended the Congo, then why should we ask you to write something original before you have had time to read all that has been already written on the subject. As a mathematical friend of mine once remarked, "A man must be pretty thoroughly soaked in his subject before he becomes original." Any originality which we in our present stage of life can expect to attain is of an insipid artificial kind—like distilled water. True originality, like an artesian fountain, can only be obtained by searching deep down into the innermost depths—and, like an artesian fountain, it is not always there. Originality is spontaneous. Like the diamonds of Africa, it may be found by searching, it may be improved by polishing, but it cannot be manufactured according to a chemical formula. Therefore I say: Do not seek to be original. A *straining* after something original is one of the greatest defects of young writers.

On the other hand, do not write your essay in the same intellectual manner in which the humorous column of a daily newspaper is composed—by a half-mechanical use of scissors and paste. By taking a scrap from this book and a scrap from that, and another from a third, and so on, and tacking them all together with a few connecting words and a very feeble idea of plan or order, your essay will have the same bewildering effect as a crazy quilt.

Do not go to either of these extremes. But take a few filaments of truth, collected by reading or observation, thoroughly assimilate them, straighten them out, arrange them in logical sequence and weave them into one harmonious whole by the woof of your own personality. You may thus revive some half-forgotten experiments, some philosophic deductions which, like Newton's second law of motion, have long been ignored or entirely misconceived. Or you may bring to the notice of the scientific world some clever contrivance, the invention of some unknown Watt, which but for you might never have reached the light of day. But in this way better than in any other will you cultivate those powers of comparison and discrimination which are essential in a good critic, and which ultimately develop into *true originality*.

If the position I now occupy is the most honourable in your gift it is also the most responsible, and I feel that I would not be doing my duty here to-day, did I not refer to another matter of vital importance to the student body. I do so with some hesitation, occasioned by doubt as to whether it is properly within my sphere, but more especially by an apprehension that my remarks may be misinterpreted and made to convey a meaning which I had never intended. I am, however, encouraged to risk these dangers in the hope that I may contribute in some measure towards the satisfactory arrangement of a difficulty which has existed for some time in our college. I refer to the relation of the first year students to the seniors. In the first place, I think the seniors are much to blame for the present state of affairs. If the new students were told plainly and kindly what is expected of them during their apprenticeship to college life there would be very few indeed who would not profit by and act according to advice thus given. This being my conviction, I am willing to create a precedent and to tell the first year men what, in my opinion, is their duty towards the seniors. I speak on this question more boldly because my long attendance at college has crystallized my opinions into articles of belief.

Be natural. Do not appear timid, for you are among friends ; nor bold, for your boldness will not go unchallenged. Consider that the seniors are your friends, and treat them as such, until they have proven themselves your enemies.

But the golden rule I would have you follow is : " Do unto others as you would have others do unto you." Treat the seniors with respect if you wish them to treat you with the same. They are entitled to respect from you because they are, in general, older than you, and have already accomplished the work at which you are now engaged, and have become familiar with the peculiarities of College Life. For, believe me, College Life is quite different from any other kind of life.

You have the solution of this question in your own hands ; if you conduct yourselves in a quiet, gentlemanly manner, paying due attention to the feelings of those who are your seniors (here, at least), you will be treated in the same way by them ; and all necessity for punishment, which is as obnoxious to the majority of the seniors as it is to you, will be done away with. But if, despising the advice of those who seek to befriend you, or inflated by the idea that you are Sir Oracle, and that besides you there is none else, or from an ignorance of the courtesies of juniors to seniors, observed in every phase of life, you seek to thrust forward your importance on every possible occasion, then you will find that you will stir up very vigorous feelings against you—feelings which may culminate in what is known as hazing. Now, it is well known that I am an opponent of hazing as it has been conducted in the past. It is in the hope that a hazing may be avoided that I am speaking as I do to-day, and if I may hurt the feelings of anyone here it is but as the knife of the skilful surgeon lances the flesh of the patient—it is for your own benefit.

I feel the more strongly urged to speak on this question since last evening at another society a very indiscreet freshman harangued the meeting, and, by " taking issue again," two of the lecturers, succeeded in rendering his position around the College at once notorious and unsafe. I am not one of those who think that during the first year a man should not open his mouth. Far from it. On the contrary, I believe that the earlier in a man's course that he takes an active part in societies, the better for the society and for himself. One of the greatest difficulties in our College societies is that men do not take an interest in them until they are about to leave College. But there is a time to speak and a time to keep silence. It is more appropriate for a new member to remain an attentive listener until he has become familiar with the procedure of the society. After the first two or three meetings you will be in a better position to acquit yourselves creditably, and I can assure you that your efforts will be kindly received.

You will be asked to contribute papers to the society before the end of the year, and I hope that you will respond cheerfully. One of the most interesting papers read in this society last session came from a member of the first year. I hope that the president next fall may be able to say that not only one but several of the best papers have emanated from you. If he can say that, he can also say that you early manifested an interest in the society, which will keep on increasing as long as you are in connection with it.

On behalf of the older members of the society I bid you welcome, and can assure you that if you treat us in a generous, kindly manner, and withal with that modicum of respect to which our academic standing entitles us, you need have no reason to fear anything from us but the kindest treatment and the most generous assistance.

*October*, 1889. JOHN A. DUFF.

# DISTANCE MEASURING MICROMETERS.

By L. B. Stewart, D.T.S.

Instruments for obtaining distances more expeditiously than by the usual method of chaining are coming into such general use that it may prove of interest to the members of the Society to give a short description of a few of the principal forms of these instruments.

Micrometers are designed for the purpose of measuring small angles with extreme accuracy. If, then, we measure with one of them the angle subtended by a rod of known length, held so as to be perpendicular to the line of sight, we can from those data determine the distance to the rod. This is, in outline, the method of determining a distance with a micrometer. The first form of micrometer I shall describe is

## THE ROCHON MICROMETER.

As a double refracting prism of rock crystal plays an important part in the construction of this instrument, it will be necessary before giving a general description of it to state a few of the laws of double refraction.

If a ray of light be incident on a doubly refracting crystal in the direction of its axis it suffers no double refraction, but if it be incident in any other direction it is doubly refracted. Let $ABC$, Fig. 2, be a portion of a crystal of rock crystal cut so that the face $AC$ is perpendicular to the optical axis of the crystal, and $ABD$ another portion cut in a direction parallel to its axis. The two faces $AC$ and $BD$ are parallel to one another, and the two pieces of crystal are firmly united. If now a ray of light $IE$ be incident normally to the surface $AC$ it will suffer no refraction at the point $E$. When, however, it encounters the second surface $AB$ it is split into two parts, the ordinary ray continuing in the same direction as before and the extraordinary ray being refracted at the point $G$ and taking the direction $GH$; it is again refracted at the point $H$, taking the new direction $HK$. No matter what angle the incident ray may make with the surface $AC$ the direction of the ordinary ray after emergence is parallel to its original direction, as the ordinary ray obeys the laws of single refraction.

Next, let $O$ be the object glass of a telescope, $OR$ its axis, and $R$ its focus. Let a rod of length $b$ be held at a distance $x$ from the objective with its length perpendicular to the axis of the telescope. An inverted image $RK$ of the rod will be formed at the focus of the objective according to the well known laws of optics, the image of any point of the rod being on the production of the line joining that point with the optical centre of the objective. Let us next examine the effect produced by placing a double refracting prism $AB$, such as has been described above, in the telescope between the objective and its focus, with its parallel faces $AC$ and $BD$ perpendicular to the axis of the telescope. From what has been stated above, each ray on meeting the dividing plane $AB$ of the prism is there split into two parts, the ordinary ray, maintaining its original direction, and the extraordinary ray, being refracted through a constant angle. Two images therefore will be formed at the focus of the objective, the one $RK$ formed by the ordinary rays occupying precisely the same position which it would occupy if the prism were not there, and that formed by the extraordinary rays occupying some other position $KM$. If the axis of the telescope be always directed to the foot of the rod the angle of deviation $RLK$ $(=\theta)$ will be constant.

I have shown in the diagram the two images $RK$ and $KM$ in contact with one another, but it is evident that if the prism be shifted along the axis of the telescope it will cause the two images to recede from one another or to overlap. Also if the distance $x$ be altered, the result will be a corresponding change in the size of the images of the rod, and a change in their relative positions. We conclude from this then that for any distance $x$ there is a corresponding position of the prism in which the two images are in contact.

Let us next investigate the relation existing between the distance $x$ and the distance of the prism from the focus. Let $m$ denote the size of the image $RK$, $u$ its distance from the objective, $\theta$ the constant angle included between the rays $RL$ and $KL$, $l$ the distance of the point $L$ from the inner principal focus of the objective,* $f$ its focal length, $b$ the length of the rod, and $x$ its distance from the objective. Then by similar triangles we have

$$\frac{x}{u} = \frac{b}{m}. \quad \text{But } m = [\,l - (f - u)\,] \tan\theta\,;$$

$$\therefore \frac{x}{u} = \frac{b}{(l-f+u)\tan\theta} = \frac{b}{u\tan\theta - (f-l)\tan\theta}.$$

But from optics $$\frac{1}{x} + \frac{1}{u} = \frac{1}{f}\,; \quad \text{or } u = \frac{fx}{x-f}.$$

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* The principal focus should be to the right of $R$.

Substituting this in the above equation—

$$\frac{x(x-f)}{fx} = \frac{b}{\dfrac{fx}{x-f}\tan\theta - (f-l)\tan\theta}$$

or

$$1 = \frac{bf}{fx\tan\theta - (x-f)(f-l)\tan\theta};$$

$$\therefore fx\tan\theta - (fx - f^2 - lx + lf)\tan\theta = bf;$$

or

$$l(x-f)\tan\theta = bf - f^2\tan\theta;$$

$$\therefore x - f = \frac{1}{l}\cdot\frac{f(b - f\tan\theta)}{\tan\theta}. \qquad (1)$$

As the fraction in the second number of this equation is constant, we conclude that the distance of the rod from the outer focus of the objective varies inversely as the distance of the prism from the inner principal focus. The distance $l$ is measured from the point $L$ (see diagram) where the two rays $FR$ and $HK$ intersect.

By transposing equation (1) it may be put under the form

$$\frac{b}{x-f} = l\cdot\frac{\tan\theta}{f\left(1 - \dfrac{f}{b}\tan\theta\right)}, \qquad (2)$$

which shews that the angle subtended by the rod at the outer focus varies directly as the distance of the prism from the inner principal focus.

In the construction of the instrument a scale is attached to the outside of the telescope, which is read by an index or vernier which is attached to the prism, and therefore moves with it. The zero of the scale is placed exactly opposite to the focus of the objective, and it is usually graduated to minutes of arc, which are subdivided to ten seconds, which are further subdivided by the vernier to single seconds.

The scale may be graduated by the help of equation (2), for, transposing (2) we have

$$l = \frac{b}{x-f}\cdot\frac{f\left(1 - \dfrac{f}{b}\tan\theta\right)}{\tan\theta}; \qquad (3)$$

from which we can find the distance $l$ corresponding to a given angle $\dfrac{b}{x-f}$ if we knew the values of all the constants in the equation. The scale can be also graduated by experiment, by placing a rod of known length at a given distance from the telescope so that its length is perpendicular to the line of sight. Then from the length of the rod and the given distance we determine the angle subtended at the outer focus of the objective. The corresponding position of the index on the scale is then found by turning the milled head which moves the prism until the two images of the extremities of the rod coincide. By fixing in this way two points on the scale the whole scale may be graduated. The rod used has generally a disc attached to each end, and in taking a reading the discs are made to coincide.

Tables have been prepared giving the distances corresponding to the different angles from 1″ to about 40′ for a rod of given length. These distances, it must be borne in mind, begin at the outer focus of the objective. I shall next consider

### THE LUGEOL MICROMETER.

This is also a double image micrometer, the double image being produced by having the object glass of the telescope divided vertically into two equal parts. Each of these parts has an independent sliding motion in a direction perpendicular to the axis of the telescope, and as an image of any object towards which the telescope may be directed is formed at the focus of each half of the objective, it follows that when the two halves are separated, the two images are also separated. The motion of the two parts of the objective is produced by means of a screw which works in two nuts attached one to each of the frames which carry the two parts of the objective. The part of the screw which works in one nut is right-handed and that which works in the other is left-handed, so that when it is turned the two halves of the objective are moved by an equal amount in opposite directions. To the screw is attached a drum head whose circumference is divided into one hundred equal parts. A scale is attached to the frame which holds one-half of the objective, on which the number of whole revolutions of the screw is read, and the fraction of a revolution is read on the graduated head. When the scale stands at zero the two images of any object should coincide, but if they do not coincide, by bringing them into coincidence and reading the scale we obtain the index error which must be applied to any reading to obtain the correct reading. We are thus provided with a means of measuring the amount of separation of the two half lenses. Let us next see how we may make use of this to determine a linear distance.

Let *A B*, Fig. 3, be a rod with a disc attached to each end. Let the telescope be directed to this rod and the images of the discs made to coincide by turning the milled head that turns the screw, then the straight lines joining the centres of the two discs *A* and *B*, with their images at $F$, will pass through the centres $C$ and $C'$ of the two half lenses. Let $b$ be the distance between the centres of the two discs, $x$ the distance of the rod from the objective, $u$ the distance from the objective to $F$, and $m$ the distance between the centres of the two half lenses. Then by similar triangles we have

$\frac{x+u}{u} = \frac{b}{m}$. But $\frac{1}{x} + \frac{1}{u} = \frac{1}{f}$, $f$ being the focal length of the lens. The last equation may be written $\frac{x+u}{u} = \frac{x}{f}$. Comparing this with the first equation we find $x = \frac{bf}{m}$.

Or the distance $x$ varies inversely as the distance $m$ between the two half lenses; $f$ and $m$ should be expressed in the same unit; $x$ will then be found in the same unit as $b$. The value of $f$ in terms of a revolution of the screw may be determined by taking a reading of the instrument when directed to a rod of known length, placed at a known distance and having the images of the discs on the rod in coincidence; by substituting these values of $x$, $b$, and $m$ in the above equation we obtain the value of $f$; $x$ and $b$, of course, should be expressed in the same unit. A table may be constructed containing the distances corresponding to the different readings of the instrument on a rod of given length. These distances begin at the object glass of the instrument.

I shall pass on next to

## STADIA MEASUREMENTS.

If two additional horizontal cross wires be attached to the diaphragm of the telescope of a transit, one above and the other below and at equal distances from the wire already there, then we have an instrument adapted for stadia measurements. If this telescope be now directed to a rod, such as a levelling rod, placed so as to be perpendicular to the line of sight, then the length on the rod intercepted between the two stadia wires, is proportional to the distance of the rod from the outer focus of the objective.

To prove this, let $b$, Fig. 4, be the distance on the rod intercepted between the stadia wires, $x$ the distance from the rod to the objective, $u$, the distance from the objective to the image of the rod, and in the distance between the stadia wires. Then by similar triangles we have

$\frac{x}{u} = \frac{b}{m}$, or $x = u\frac{b}{m}$. As $u$ varies with the distance of the rod we cannot employ this equation for determining $x$, but from optics we have $\frac{1}{x} + \frac{1}{u} = \frac{1}{f}$; or $\frac{1}{u} = \frac{1}{f} - \frac{1}{x}$.

Substituting this in the above equation we have $x\left(\frac{1}{f} - \frac{1}{x}\right) = \frac{b}{m}$; or $\frac{x}{f} - 1 = \frac{b}{m}$; or $x - f = b\frac{f}{m}$.

This proves the statement made above. The constant term $\frac{f}{m}$ can best be determined by experiment, by reading the rod at several measured distances.

In this form of micrometer, we see that the base or length of the rod is the variable quantity, the angle at the outer focus of the objective being constant, while in the two former instruments the base is constant and the angle variable.

As the rod has to be read from the instrument it is evident that this method can only be used at short distances, but at short distances very good results may be obtained. By using a rod similar to the target rod used in levelling, the distance at which it can be used may be greatly extended, and probably much greater accuracy secured.

The distance in this method as in the case of the Rochon micrometer begins at the outer focus of the objective.

For a great deal of the information contained in this paper I am indebted to a paper on the same subject by W. F. King, Esq., read before the Association of Dominion Land Surveyors.

# TOWNSHIP SURVEY.

By W. Russel.

The Government of Ontario is gradually dividing up all lands in the Province of value to the settler. The land is first divided up into townships, which are again sub-divided into concessions and lots. Every year the Government sends out surveyors to divide up these townships, of which, last year there were ten given out, the greater number being at the head of Lake Temiscamingue, the source of the Ottawa River. A great number of these inland townships are six miles square, and the sub-division of these will form the principal part of this short paper.

The system, as now followed in sub-dividing these townships, is the 640-acre system.

Formerly townships were laid off along the river or lake front, the East and West boundaries running in a northerly course, and the concession lines running East and West. In this system concession lines were only run, although side road allowances were left. In some cases three lines were run parallel to the East and West boundaries, which were called East Quarter, West Quarter and Centre township lines. The lots usually had a width of from 10 to 13 chains, and a length of from 80 to 110 chains.

Several systems followed this, according to the change in legislation, arriving at last at the present 640-acre system.

This consists in dividing the township into blocks of one mile square. Astronomical lines are run North and South, East and West across the township—that is, parallel to the township lines. Each square mile is sub-divided into two lots by an imaginary line running North and South midway between the East and West lines. Each lot will therefore contain 320 acres. The lines running East and West divide the township into concessions, and are called concession lines; whilst the lines running North and South are called side lines. The lots are numbered from East to West, so that in a six-mile township the lots number from one to twelve, while the concessions number from one to six, numbering from South to North. See figure 6.

The instruments used on such surveys by most surveyors are the transit theodolite, surveyor's compass, Gunter's 66-foot chain, and the micrometer. In running lines the transit and compass are used, and in measuring them the 66-foot chain is used.

The party is divided into two parts, one headed by the surveyor and the other by his assistant, each party has from two to four choppers. The surveyor takes the instrument and his assistant the compass, or *vice versa*—the lines being chained as they are run.

The lines are not run straight across the township at the one time, but all lines within a certain radius are run, and continued when camp is moved and a similar process is gone through. In this way great care must be taken in recording the measurements of lines and in turning angles, as a small error in the angle at the start will throw the line out to a great extent in six miles. In case an error is found, it can be corrected by the use of the radian system, with which we are all familiar. This, when calculated out, shows that 20 links subtend an angle of about eight minutes at the distance of one mile.

In rough and broken country a great part of the error may be ascribed to bad chainage, unless great care is taken by the chainmen, as a very small error in each chain may cause a large one in a mile.

The lines are chopped wide enough to admit of a clear sight with the telescope, and are well cleared out. The adjacent trees are distinctly blazed on three sides, those being on each side in the direction of the line, and on the side along which the line passes. The posts, which are placed every mile on North and South lines, and every half mile on East and West lines, are made of durable wood; their dimensions, above ground, being about two feet high and six inches square. They have the number of the concession on their North side, and number of the lots on their East and West side, which is done with a scribing iron, carried by the chainmen. They are firmly planted in the ground, and two trees close by conspicuously blazed and marked B.T. (bearing tree), the position of the trees with regard to the post, and dimensions are entered in the field book, so that, in case the post were lost, it could be replaced by consulting the notes.

In chaining the lines a smoothed stick about four feet long, called a tally stick, is used by the chainmen, and placed in the ground every ten chains, commencing at a mile or half-mile post. On it are marked the number of chains, so that in case the count is forgotten, by referring back to the last tally stick it may be found, which would be different if such were not the case, as the chainmen would then have to go back to the post perhaps thirty chains back.

In a survey of this kind the surveyors are paid by the job, hence the necessity of fast work and the free use of the compass. When the exact variation of the needle is known for a certain locality, lines are thus run with great speed and with very fair results. One great danger in running a compass is in encountering magnetic iron ore, which abounds so frequently in Ontario, but by keeping a close back sight this error may be avoided.

All lakes and rivers found in the township are traversed and connected with the concessions or side lines. The old way of surveying lakes and rivers was to run a line along the shore and take offsets at different points, each change in direction of the line being noted. The method as now followed by most surveyors is as follows:—

The surveyor stations himself at some convenient place with a compass and micrometer, and sends an assistant round to different points along the lake with a disc of known diameter; the surveyor takes the bearing of these points from his station, and the distance with the micrometer. In this manner the lake may be easily surveyed, and then plotted on paper.

In some cases, when the whole lake cannot be seen from one station, new stations are taken up, each being connected with the one preceding it. In case of a lake with steep banks, a canoe is sometimes used, and poles driven in near the shore to represent stations. In surveying a river the same method applies, the man in the front boat using his own judgment as regards locating the different stations, which should be on all the prominent bends in the river.

When the survey is finished a plan on a scale of forty chains to the inch is drawn, showing the natural features of the country, area of all the lots, regular or irregular, the area of all lakes and streams in acres, and the total area of the survey. The surveyor is paid so much per acre.

The field notes are copied in India ink. A timber map is also prepared, showing the different kinds of timber found in the township. All good samples of ores found on the survey are preserved, and with all reports are sent to the Department of Crown Lands at Toronto.

# ONTARIO CEMENTS.

By F. M. Bowman.

In treating this subject I shall deal with it under three divisions, viz. :—

1. Cement deposits of Ontario.
2. Testing cements with special reference to causes for discrepancies in reports of different experimenters.
3. Comparative value of Canadian cements.

I shall not deal with the details of the manufacture, nature, and use of cements; this subject, though important, would scarcely lie within the objects of this paper. I shall merely review briefly the general classification of cements.

*Hydraulic Cements* are made from those limestones which, when burnt, do not slake with water, but which, when the burnt product is finely ground, will harden under water. The term "hydraulic" is used to signify this property of hardening under water. Certain other limestones will, when burnt, slake with water and will also, when ground, harden under water. The product of these limestones, known as *Hydraulic Lime*, has the hydraulic property less marked than the cement. These hydraulic limes slack more slowly and swell less in proportion to their hydraulicity. Artificial hydraulic limes and cements, of first-class quality, are often made by mixing lime and clay thoroughly together; then moulding the mixture into blocks, like bricks, which are first dried, then burnt and finely ground. The well-known Portland Cement is an artificial cement made by grinding together in water, chalk and clay. The fine particles are floated away to other vessels, and allowed to settle as a paste; which is then collected, moulded, dried, burnt and ground. Natural Portland is that made from limestone, or other material of very rare occurrence, which combines naturally that proportion of lime and clay which gives the above artificial Portlands their pre-eminence. This alone constitutes its difference from our common natural hydraulic cements.

## I. CEMENT DEPOSITS OF ONTARIO.

In Ontario, raw cement stones of minor importance are found at Rockwood, Limehouse, Georgetown, Cayuga, Ramsay and Nepean.

We shall, however, confine our attention to the cement deposits of the more important localities, namely: Thorold, Queenston, Napanee and Owen Sound. These cements are the cements met with most frequently in practice and a description of their location and history may be interesting and useful.

THOROLD AND QUEENSTON CEMENTS.—From information furnished me by the manufacturers of these cements, I quote you the following:

*Re* THOROLD CEMENT.—"The Thorold Cement was first manufactured in the year 1841, by the late Mr. John Brown, the well-known contractor. He used the cement exclusively in the prominent works which he built throughout the country. Mr. Brown never pushed the sale of his cement and hence it never came prominently before the public. In 1876, Mr. John Battle purchased from the estate of Mr. Brown, the cement quarries and mills, and immediately began to push the sale and succeeded so well in doing so that at the present time, it is used extensively in almost every city, town and village in the province.

"The Thorold Hydraulic Cement is made from a natural cement rock found at Thorold, Ont., where it is quarried carefully, and thoroughly burned, finely ground and shipped in barrels, paper or jute sacks, or bulk, as may be ordered. The cement rock occurs in the Niagara bed of limestone and its colour before burning is comcommonly dark-bluish, gray to drab; it is most carefully selected and produces a cement of uniform quality.

"The following are some of the uses to which it is well adapted: Abutments and piers for bridges, artificial stone for building, concrete for foundations, cement drain pipe, cisterns, floors for cellars and stables, for laying tile and marble floors, mill-dams and aqueduct works, in fact, for all places where a first-class cement is required.

"The Thorold Hydraulic Cement was used in the construction of the Victoria Bridge, at Montreal; the towers of the old Suspension Bridge (Railway) and the Canadian abutments, and approaches of the Cantilever Bridge, at Niagara Falls, Ontario; the International Bridge, at Fort Erie, and in the construction of the old and new Welland Canals. This cement has also been used and is still being used on the Grand Trunk Railway and the Canadian Pacific Railway, and many other works too numerous to mention."

*Re* QUEENSTON CEMENT.—"The Queenston Cement was first manufactured in 1886 by the Ontario Cement Co. In the following year the business changed hands, becoming the property of Messrs. Isaac

Usher & Sons, of Thorold, Ont., who have carried it on quite successfully since. The Queenston Cement is much the same as the Thorold, but is considerably darker in colour. It is well adapted for all building and concrete work and is at present being exclusively used by the Michigan Central Railway, and also in the town of Windsor in the building of sewers."

NAPANEE CEMENT.—"The property of this company consists of quarry lands containing an almost unlimited quantity of first-class native cement rock and also limestone suitable for roach lime.

An analysis of this cement gives the following:

| | |
|---|---|
| Silicic Acid | 28·43 |
| Alumina | 10·50 |
| Lime | 43·05 |
| Magnesia | 18·02 |
| | 100.00 |

The cement manufactured by this company is largely used for cisterns, cellar floors, dams, bridge piers, culverts and all classes of masonry.

It has been used extensively on the principal railways of Canada, on the Lachine, Cornwall and Murray Canals; the insane asylum building at Mimico and Orillia; the public works and sewers of Toronto and many of the principal cities of Ontario; for water-works, reservoirs, etc.

OWEN SOUND CEMENT.—The discovery of this new deposit was made by Mr. R. J. Doyle, an Owen Sound business man, while camping in the vicinity some years ago. The discovery is a promising one and may well be hailed with considerable expectancy by our engineers and contractors, since all the necessary ingredients are said to be present for the manufacture of the best natural Portland cement. Hitherto it has been necessary to import this article from England, the cements made on this side of the Atlantic being of an inferior quality, but, should this new cement prove to be as good as its promoters anticipate, all this may be reversed. The find is situated in the bed of Shallow Lake, nine miles west of Owen Sound. The lake is remarkable from the fact that during the fall and winter it covers an area of one by nearly two miles to the depth of four feet and entirely disappears in the dry season, leaving the ground with but little trace of its occupancy. The water departs by means of sink holes and is said to issue from the ground again at different places and empty into Lake Huron.

The bed of this lake has a deposit of nearly five hundred acres covered with carbonate of lime to a depth of from four to seven feet, underneath which, strange and providential as it may seem, is a deposit of clay eminently fitted for the manufacture of first-class cement. Beneath this, again, is a strata of fire-brick clay.

Similar deposits have been found elsewhere in Canada, but their possible economic value has not yet been determined and no attempt to develop them has been made.

The company turn out more than one hundred barrels per day. Specimens which have been officially tested have stood higher strains than any other cements, one example of neat cement, after being seven days in water, breaking under the very great tensile stress of 675 lbs. per square inch, and it is believed by some that Canada now has a cement equalled only by those of England and Germany.

## II. TESTING CEMENTS WITH SPECIAL REFERENCE TO CAUSES FOR DISCREPANCIES IN REPORTS OF DIFFERENT EXPERIMENTERS.

One matter, which I wish especially to call your attention to in the matter of testing cements, is the fact that most of the tests made in this country and in England are carried on for the purpose of determining the tensile strength of neat cement, while in practice, cement is seldom used without the admixture of sand. In Europe, on the other hand, the practice was established about twelve years ago of testing the cement when mixed with sand in the proportion of three to one by volume. The value of a cement evidently depends upon its power of giving the greatest strength when combined with the largest proportion of sand (within certain limits), and the day is probably not far off, when all engineers (as some do now) will test cements in combination with sand, instead of neat as at present.

Numerous experiments by a great number of observers in different countries have shown beyond dispute that heavy, well-burnt cements, which when tested neat have given high results, have notwithstanding, when mixed with sand, turned out disproportionately weak, and in general it may be said that the greater the proportion of sand in the cement tested, the more accurately can the actual cementing quality of the cement be indicated. With regard to the character of the sand used for the purpose much might be said. In all tests, coarse, angular, gritty and clean sand should, as far as possible, be used; coarse sand being such as will pass through a sieve of sixty four meshes per square inch and be retained by one of 289 meshes per square inch. It is however generally conceded by experts that a small amount of fine particles in the sand, to the extent of not more than 20 per cent. of the sand used, will not affect the strength of the mortar injuriously, and with some kinds of cement it may even act beneficially.

In testing cements, importance should be attached to the results obtained from the experiments made at the end of the longer time of hardening. Long experience has shown that no proper conclusions can be drawn from tests made with neat cement, after an interval of only seven days.

If the relative strength of two or more cements has to be ascertained, not only must all the conditions be uniformly observed, but, for accuracy, many months must be allowed to elapse between making the briquettes and testing them. It has frequently been found that those cements which, at the earlier stages, were apparently the weaker, afterwards overtake the stronger. Indeed very little value should be attached to experiments with neat cement made at the end of a week; and they should only be used for marking a stage in the growth of the strength, or where, from unavoidable circumstances, it becomes necessary to ascertain, quickly and only approximately, the quality of a cement. As in testing with briquettes of sand and cement the process of hardening goes on at a slower rate than with neat, twenty-eight days has by pretty general consent been adopted as the earliest time for ascertaining their approximate value when made of three parts of sand to one part of cement. Here however, our results are almost as uncertain as those obtained from neat cement after seven days in water, and here too it will often be found that those which at this stage lead the way, fall off at a later.

I have already referred to the necessity of having uniformity of conditions in making experiments for determining the relative value of two or more cements. I cannot emphasize the fact too strongly that the slightest want of uniformity in the smallest appreciable condition will effect the results to an extent which will make them worthless for comparison, and which only those who have had considerable experience could believe.

One of the main causes for descrepancies in the tests of different persons on the same cement is due to a variation in the temperature of the air and water. In one case a bar moulded in air at 60° F. after six days in water of 40°, broke with 113 lbs. tension per square inch, while those in water at 70° F., required 254 lbs. or about 2.25 times as much. The strength of cements is also affected by the degree of force with which the cement is pressed into the moulds; by the extent of setting before being put into water, and of drying when taken out ; and still more by the consideration of whether or not it sets while under the influence of pressure, which increases the strength materially. These together with the thoroughness of the mixing or gauging, the quantity of water used may affect the results 100 per cent. or even much more. For these reasons, the results of different experimenters on different cements should scarcely ever be used for the purpose of determining the relative merits of various cements.

### DIVISION III.

We come now to the last division of our subject, viz.: The comparative value of Canadian cements. Only recently I was chatting with one of our local engineers, and in answer to the question of the value and use of Canadian cements he said simply, referring to their use in bridges, " They are no use for foundations, but good enough in the superstructure." This I believe describes our cements almost perfectly. There can be but one opinion with regard to our cements, and that is that the manufacturers have been too careless and have shown a wonderful lack of thoroughness in the manufacture of their cement.

The results of experiments, which I quote you later on, show most conclusively that our native cements are a most inferior article compared with American cements of the same nature. No fault of this can be attached to the material itself, for we have material as good as the best and in almost unlimited quantity. The blame for this state of affairs rests, I think, chiefly with the engineer. The manufacturer is scarcely responsible, for he makes what he can sell, and if the engineer takes everything he makes, he will certainly make what is cheapest rather than what is best. The blame lies greatly among the members of the engineering profession, and to secure a good native cement is only a question of persistent demand on their part. Let the engineer in all his specifications fix a certain strength for the cement to be used and insist upon that strength, and let him make frequent tests. This would do more and probably is doing more than anything else towards improving our cements for it now seems that the manufacturers begin to realise what cement ought to be and what it might be, and the poorer article is being driven out of the market.

Various bad tendencies have been noticeable in our native cements. In the Queenston cement a tendency to contract in setting is one fault. The presence of too much free lime, causing blowing, is a fault existing in almost all our cements but especially noticeable in the Napanee. But the criterion of a good cement is its tensile strength and that our cement lacks in this may be seen at once by a reference to the following results of tests made for the American Society of Civil Engineers :

| | TENSILE STRENGTH IN POUNDS AFTER | | |
|---|---|---|---|
| | I YEAR IN WATER. | 30 DAYS. | 6 DAYS. |
| Portland, neat | 450 to 800 | 350 to 700 | 250 to 550 |
| American Natural, neat | 300 to 400 | | 60 to 100 |
| Canadian Natural, neat | 170 to 210 | | 10 to 70 |

The following is a more complete list of experiments, being the tensile strength as determined principally by Mr. Rust for the Canadian Society of Civil Engineers of a number of samples of cements tested during 1885-6-7:—

*By Mr. Rust.*

| Brand. | Time in Air. | In water | Proportion. | Lbs. per sq. in. | Remarks. |
|---|---|---|---|---|---|
| Napanee ....... | 24 hours | 1 Year | Neat | 180 | Average of 6 briquettes |
| | do | 30 days | do | 76 | do 12 do |
| | do | 6 days | do | 39 | do 30 do |
| | do | 1 year | 2 (sand) to 1 | 150 | |
| | do | 30 days | do | 25 | |
| Thorold ........ | do | 1 year | Neat | 210 | do 3 do |
| | do | 30 days | do | 85 | do 8 do |
| | do | 6 days | do | 42 | do 40 do |
| | do | 1 year | 2 to 1 | 150 | do 3 do |
| | do | 30 days | do | 50 | do 10 do |
| American....... | do | 30 days | Neat | 110 | do 3 do |
| Natural Cement | do | 6 days | do | 78 | do 8 do |
| Cumberland .... | do | 30 days | 3 to 1 | 50 | |
| | do | 30 days | do | 25 | |
| Portland ....... | do | 1 year | Neat | 475 | |
| | do | 30 days | do | 320 | do 3 do |
| | do | 6 days | do | 220 | do 16 do |
| | do | 60 days | 3 to 1 | 105 | do 6 do (coarse sand.) |
| | do | 60 days | do | 63 | Average of 8 briquettes (equal parts coarse and fine sand.) |
| Georgetown..... | do | ........ | ............... | ........ | The several samples fell to pieces after being in the water a few hours. |

*By Grad. S. P. S.*

| | | | | | |
|---|---|---|---|---|---|
| Queenston. . . . . | 24 hours | 6 days | Neat | 33 | Home-made testing machine. |

*By M. J. Butler, for manufacturers during* 1887–9.

| | | | | | |
|---|---|---|---|---|---|
| Napanee. . . . . . . | | 1 yr & ovr | Neat | 185-300 | Result of 20 experiments |
| | | 7-30 d'ys | do | 95-200 | do 6 do |

I shall not elaborate on these tests. They show clearly that our cements fall below the standard required. However, these tests were made mostly previous to 1887. The later ones show improvement. I have no doubt that were the tests repeated again the results would show a marked improvement, and we may look with confidence to the future development of this branch of Canadian commerce.

# EXTRACT FROM LETTER FROM MR. H. E. T. HAULTAIN.

Coosheen Mine, Schull,
County Cork, Ireland.

*My Dear Mr. President and Gentlemen :*

* * * * * * *

I had intended leaving in July or August for Freiburg in Saxony to attend the course in mining there ; but an old friend of my father, a mining and civil engineer, recommended me to put in a year at practical work, and asked me to stay with him. I decided to put off Germany for a year.

He sent me down here at less than twenty-four hours' notice. His instructions were : " They are testing old ground for new lode ; keep accounts, send reports, make assays ; you will find all you want in the old assay house there ; pay the men ; look after them ; do the best you can ; copper mine may contain silver ; be off by first boat."

" But I have never done any copper assaying," I said. " Oh, easy, very easy. Do the best you can ; test what they have already won and all the ore as it comes up. When does your first boat go ? " This was the extent of my instructions. " Do the best you can."

I travelled from London to Holyhead, and then to Dublin, and then to Cork, and then to Skibbereen, *via* Drimoleague, and then by narrow-gauge to Schull, *via* Bally-de-hob. Talk about Indian names, Irish beat them out and out. A stranger in a strange land with instructions to do the best I could with what I knew hardly anything about.

Schull is a small fishing village on one side of a harbour, and Coosheen is little more than the ruins of the old mining houses on the other side of the harbour.

* * * * * * *

I had been told to make assays of the ore already won. I was told I would find the old assay house, with furnaces, crucibles, chemicals, etc. The assay house consisted of a floor, four walls, and some remains of a roof and the furnaces.

Of the chemicals and crucibles, not a thing, and the only bit of apparatus to be found was a rusty old pair of pocket scales.

I reported the state of affairs, and after some delay was sent six crucibles, and was told to do the best I could for the rest.

After a great deal of trouble ( for though I am in the greatest and most civilized empire in the world, it is next to impossible to get what you want in this outlandish part of it) I managed to get a pestle and mortar, and some borax, sodium bicarbonate, etc., and set to work to make assays in the blacksmith's forge. I tried to work after the way we do with the blow-pipe and carb.-soda, etc. I had great difficulty in keeping up sufficient heat for a long enough time, but after some failures I got some fairly satisfactory results.

I got a good book on the subject, managed to build two furnaces, got a lot of crucibles, and got coke instead of coal, which contained a great deal of sulphur.

The proper way to make assays of copper ore is to first roast the ore, after having weighed it of course, then to fuse for "regulus," then to calcine the "regulus," then fuse for coarse copper, then fusing again with certain other fluxes, called "washing," and then re-fusing.

This long process gives you a button pretty free from iron, lead, antimony, etc.

From want of apparatus and fluxes I tried to skip all this and worked with two operations, roasting, and fusing with borax, sugar, carbonate of soda, saltpetre and salt.

After a good many failures I got pretty good results, but the fusing required upwards of seven hours in the furnace. The heat from the coke was very great ; some common bricks that got into the furnace by mistake melted like wax.

The results, though not very correct, were good enough for the present occasion. The ores of copper we have come across are grey ore, variegated ore, peacock ore, azurite, malachite, the red oxide and the chloride.

* * * * * * *

# OFFSETS FROM TANGENT ON A 1° CURVE.

By T. S. Russell.

The following table will be found useful to railway engineers. There are cases, of frequent occurrence in railway work both on location and construction, when it is necessary to lay out a curve, or a part of a curve, without a transit. In such cases this table can be used, either for finding the actual offsets from the tangent for different points on the curve, or for finding the lengths of ordinates from chords of different lengths.

To illustrate the use of this table draw a diagram representing any length of a railway curve—say 600 feet. Draw the chord for this 600 feet of curve and draw a tangent to the curve at its middle point; this tangent will of course be parallel to the chord. Now number the 100 foot points, or stations on the curve in regular order, calling one end of the chord sta. 0, the end of the first 100 feet sta. 1, the end of the second 100 feet sta. 2, and so on. The tangent will touch the curve at sta. 3 and the chord will end at sta. 6. Then it will be readily seen that the middle ordinate of the curve at sta. 3 is equal to the offset from tangent for 300 feet of a curve with the same radius; the ordinate at sta. 2 is the offset from tangent for 300 feet *minus* the offset from tangent for 100 feet; also the ordinate at sta. 1 is the offset from tangent for 300 feet *minus* the offset from tangent for 200 feet. Similarly ordinates may be calculated for any intermediate points on this curve.

These offsets here given are calculated for all distances on the curve from 0 to 500 feet, and are for a 1° curve or a curve of 5,730 feet radius. To find the offset from tangent for any distance on any curve of different radius, take the tabular offset here given for the given distance and multiply it by the degree of the curve, expressed in degrees and decimals of a degree. Thus in the table the offset from tangent for 145 feet is 1·835 feet, therefore for a 2° curve the offset for 145 feet will be 3·67 feet; for a 2° 30′ curve the offset for 145 feet will be 4·637 feet, and so on.

The Engineering Society is indebted to H. Bannister, A. M. Can. Soc. C. E., for this useful table:

## OFFSETS FROM A TANGENT ON A 1° CURVE.

In any other curve multiply the quantity given in this Table by the degree of curve (in decimals).

| FEET | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .000 | .000 | .000 | .000 | .001 | .002 | .003 | .004 | .006 | .008 |
| 10 | .008 | .009 | .012 | .015 | .016 | .020 | .023 | .025 | .029 | .033 |
| 20 | .035 | .036 | .042 | .047 | .049 | .051 | .060 | .063 | .065 | .076 |
| 30 | .078 | .081 | .093 | .096 | .099 | .102 | .115 | .118 | .122 | .136 |
| 40 | .140 | .143 | .159 | .162 | .166 | .170 | .187 | .191 | .195 | .214 |
| 50 | .218 | .222 | .242 | .246 | .251 | .256 | .277 | .282 | .287 | .309 |
| 60 | .314 | .319 | .343 | .348 | .354 | .359 | .384 | .390 | .395 | .421 |
| 70 | .427 | .434 | .450 | .467 | .474 | .491 | .508 | .515 | .533 | .551 |
| 80 | .558 | .565 | .596 | .604 | .611 | .630 | .650 | .658 | .678 | .699 |
| 90 | .707 | .715 | .736 | .757 | .766 | .787 | .810 | .818 | .841 | .864 |
| 100 | .873 | .881 | .920 | .929 | .937 | .962 | .987 | .996 | 1.005 | 1.046 |
| 110 | 1.055 | 1.065 | 1.108 | 1.117 | 1.127 | 1.155 | 1.181 | 1.191 | 1.201 | 1.246 |
| 120 | 1.257 | 1.267 | 1.313 | 1.324 | 1.335 | 1.362 | 1.393 | 1.404 | 1.415 | 1.463 |
| 130 | 1.475 | 1.486 | 1.516 | 1.547 | 1.559 | 1.590 | 1.622 | 1.634 | 1.665 | 1.698 |
| 140 | 1.710 | 1.723 | 1.755 | 1.788 | 1.801 | 1.833 | 1.868 | 1.881 | 1.916 | 1.950 |
| 150 | 1.963 | 1.977 | 2.018 | 2.047 | 2.061 | 2.096 | 2.133 | 2.146 | 2.183 | 2.220 |
| 160 | 2.234 | 2.248 | 2.285 | 2.323 | 2.337 | 2.377 | 2.414 | 2.429 | 2.459 | 2.507 |
| 170 | 2.530 | 2.537 | 2.576 | 2.619 | 2.632 | 2.672 | 2.713 | 2.729 | 2.770 | 2.812 |
| 180 | 2.827 | 2.86 | 2.88 | 2.92 | 2.94 | 2.98 | 3.02 | 3.05 | 3.08 | 3.12 |
| 190 | 3.15 | 3.17 | 3.20 | 3.25 | 3.28 | 3.31 | 3.35 | 3.38 | 3.41 | 3.45 |
| 200 | 3.49 | 3.52 | 3.55 | 3.59 | 3.62 | 3.66 | 3.71 | 3.74 | 3.77 | 3.80 |
| 210 | 3.84 | 3.88 | 3.92 | 3.95 | 3.99 | 4.03 | 4.07 | 4.10 | 4.14 | 4.18 |
| 220 | 4.22 | 4.26 | 4.30 | 4.33 | 4.37 | 4.41 | 4.45 | 4.49 | 4.53 | 4.57 |
| 230 | 4.61 | 4.65 | 4.69 | 4.73 | 4.77 | 4.81 | 4.85 | 4.89 | 4.93 | 4.97 |
| 240 | 5.02 | 5.06 | 5.10 | 5.15 | 5.19 | 5.23 | 5.27 | 5.32 | 5.36 | 5.40 |
| 250 | 5.45 | 5.49 | 5.53 | 5.58 | 5.62 | 5.66 | 5.71 | 5.75 | 5.80 | 5.84 |
| 260 | 5.89 | 5.93 | 5.98 | 6.03 | 6.07 | 6.12 | 6.17 | 6.21 | 6.26 | 6.30 |
| 270 | 6.35 | 6.40 | 6.45 | 6.50 | 6.54 | 6.59 | 6.64 | 6.68 | 6.74 | 6.78 |
| 280 | 6.83 | 6.88 | 6.93 | 6.98 | 7.03 | 7.08 | 7.13 | 7.18 | 7.23 | 7.28 |
| 290 | 7.33 | 7.38 | 7.43 | 7.48 | 7.53 | 7.58 | 7.60 | 7.68 | 7.73 | 7.78 |
| 300 | 7.84 | 7.89 | 7.94 | 8.00 | 8.05 | 8.10 | 8.16 | 8.21 | 8.26 | 8.32 |
| 310 | 8.37 | 8.42 | 8.48 | 8.54 | 8.59 | 8.64 | 8.70 | 8.75 | 8.81 | 8.87 |
| 320 | 8.92 | 8.97 | 9.03 | 9.09 | 9.14 | 9.20 | 9.26 | 9.31 | 9.37 | 9.43 |
| 330 | 9.48 | 9.54 | 9.60 | 9.66 | 9.72 | 9.78 | 9.83 | 9.89 | 9.95 | 10.01 |
| 340 | 10.07 | 10.13 | 10.19 | 10.25 | 10.31 | 10.37 | 10.43 | 10.49 | 10.55 | 10.61 |
| 350 | 10.67 | 10.73 | 10.79 | 10.85 | 10.91 | 10.97 | 11.04 | 11.10 | 11.16 | 11.22 |
| 360 | 11.29 | 11.35 | 11.41 | 11.48 | 11.54 | 11.60 | 11.66 | 11.73 | 11.79 | 11.86 |
| 370 | 11.92 | 11.98 | 12.05 | 12.11 | 12.18 | 12.24 | 12.31 | 12.37 | 12.44 | 12.51 |
| 380 | 12.57 | 12.64 | 12.71 | 12.77 | 12.84 | 12.91 | 12.97 | 13.04 | 13.11 | 13.17 |
| 390 | 13.24 | 13.31 | 13.38 | 13.45 | 13.52 | 13.58 | 13.65 | 13.72 | 13.79 | 13.86 |
| 400 | 13.93 | 14.00 | 14.07 | 14.14 | 14.21 | 14.28 | 14.35 | 14.42 | 14.49 | 14.56 |
| 410 | 14.63 | 14.70 | 14.77 | 14.85 | 14.92 | 14.99 | 15.06 | 15.13 | 15.20 | 15.28 |
| 420 | 15.35 | 15.42 | 15.50 | 15.57 | 15.64 | 15.72 | 15.79 | 15.87 | 15.94 | 16.01 |
| 430 | 16.09 | 16.16 | 16.24 | 16.32 | 16.39 | 16.46 | 16.54 | 16.62 | 16.70 | 16.77 |
| 440 | 16.84 | 16.92 | 17.00 | 17.08 | 17.15 | 17.23 | 17.31 | 17.38 | 17.46 | 17.54 |
| 450 | 17.62 | 17.69 | 17.77 | 17.85 | 17.93 | 18.01 | 18.09 | 18.17 | 18.25 | 18.33 |
| 460 | 18.41 | 18.49 | 18.57 | 18.65 | 18.73 | 18.81 | 18.89 | 18.97 | 19.05 | 19.13 |
| 470 | 19.22 | 19.30 | 19.38 | 19.46 | 19.54 | 19.62 | 19.71 | 19.79 | 19.87 | 19.96 |
| 480 | 20.04 | 20.12 | 20.21 | 20.29 | 20.37 | 20.45 | 20.54 | 20.62 | 20.71 | 20.79 |
| 490 | 20.88 | 20.96 | 21.05 | 21.13 | 21.22 | 21.30 | 21.39 | 21.47 | 21.56 | 21.65 |
| 500 | 21.74 | 21.83 | 21.91 | 22.00 | 22.08 | 22.17 | 22.26 | 22.35 | 22.44 | 22.53 |

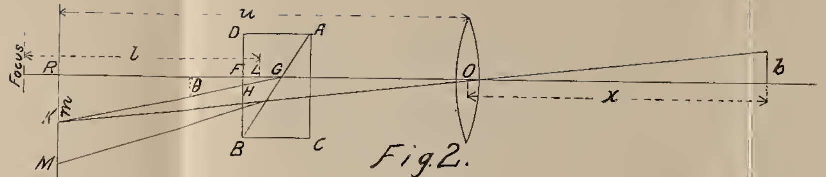

Fig. 2.

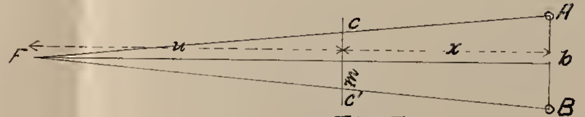

Fig. 3.

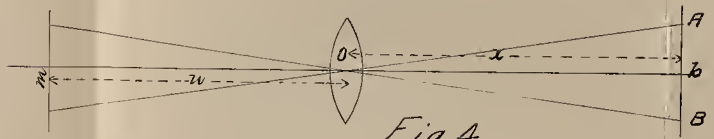

Fig. 4.

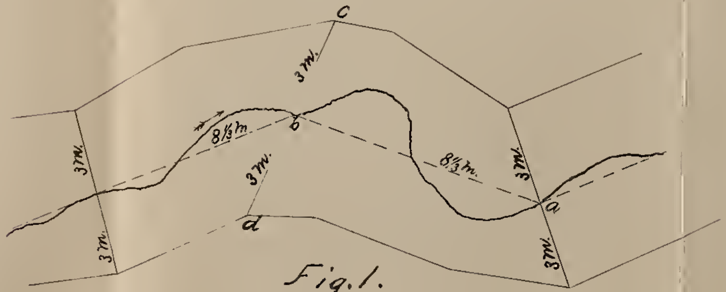

Fig. 1.

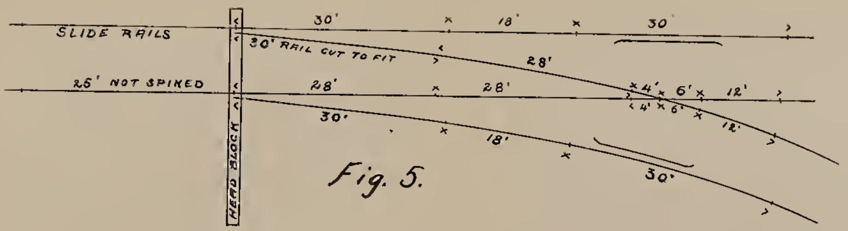

Fig. 5.

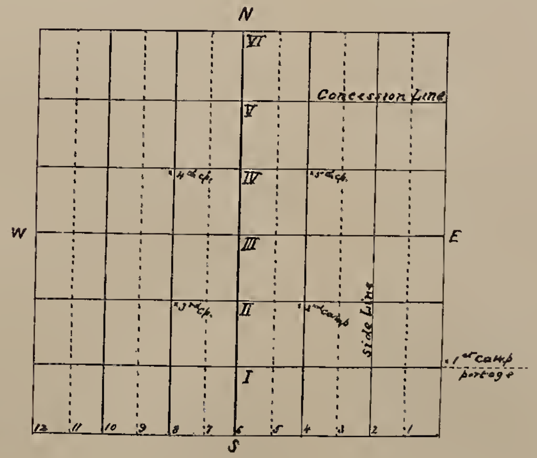

Fig. 6.

No. 4 1890-91

# ◁PAPERS▷

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# PREFACE.

The Engineering Society of the Ontario School of Practical Science, was founded in the spring of 1885, by the students in the department of engineering of that year, assisted by Professor Galbraith.

Its officers are elected yearly, and form the Executive Board of the Society.

Regular meetings of the Society are held every alternate Tuesday during the session of the School, at which papers are read and questions upon engineering matters discussed.

The Society has yearly increased in membership and usefulness.

In order to present to every member in good form for reading and reference, and to hold the interest and sympathy of all graduates in the work of the Society, the best papers are published yearly. This edition contains only those read before the Society during the year 1890.

Most of the papers have been prepared by students of this School, a special exception, however, is the paper by Dr. Bryce.

The Society has during the year received valuable papers and letters from H. E. T. Haultain, J. A. Duff, B.A., E. F. Ball, and other graduates, and hopefully expects that graduates and members of the Society in actual practice will continue to prepare papers, plans, estimates, specifications, or other matter to be read at the meetings of the Society, or filed in the library; and, moreover, will welcome and duly acknowledge similar contributions from those of the profession not directly connected with the Society.

One thousand copies of this edition will be printed for distribution to Engineers and Surveyors, and for exchange with kindred Societies.

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which are divided as follows: Thirty-five in the Civil Engineering Department, thirteen in the Mechanical Engineering, and five in Architecture. Success to them.

We civil engineers may feel proud of our new instruments, models, drawings, and testing machines; the mechanical, of their models, drawings, and machinery, to demonstrate their study by actual contact and practice; the architects, of their models, drawings and photographic collection; and we all of our library, large, comfortable, and convenient.

With these facilities and conveniences, and the staff, with its additions, Messrs. Rosebrugh and Wright, the school becomes more efficient, and confers honor upon these graduates and its past work, and encourages those who are now or will become students of this school.

It is a source of pleasure to see, in apparent appreciation of the efforts of the Government of the country and this school to make it efficient and worthy of esteem and patronage, so many new students for the various branches. On my own behalf and that of this Society, I welcome you to this meeting and Society, and hope that you will all now, as you certainly will sooner or later, become useful and interested members. Very many students make a sad mistake in looking with doubts and suspicions upon the aims and benefits of this Society and their fellow-students generally. They defer becoming members until the Society has proved itself by report, which, obviously, it cannot do, unless many of the first year students attend and become its supporters and champions; and by the time they become convinced of the benefits of attending our meetings, hearing papers on various engineering and architectural subjects read and discussed, and see the advantages of the library, they have lost much time and benefit, and care not to pay the regulation fee of one dollar for the balance of the year. Again, many look upon the Society as a means of extracting another dollar from their pockets without giving any return but loss of time. To such I will say, do not entertain such an idea; or you will regret it and feel heartily ashamed of yourself before the term is over.

Become members at once and cultivate personal acquaintance with your fellow-students outside your own year, and you will find yourself improved, and the wearisome routine of work broken and made cheerful by acquaintance that will quickly develop friendship if you prove true and worthy students of this institution and of the profession that you signify by your presence here you intend to follow.

It is not expected or possible that students of the first year can make themselves as useful in this Society as they can later, after becoming familiar with the work of the school, and the aims and usages of the Society. Yet it is a credit for students of the first year to render their share of assistance, to be willing when requested to give a paper, or work upon a committee, and thus render themselves capable of further usefulness.

And now, before turning my attention from the first year students, there is another phase of disposition that should be guarded against by all those whose sense of the rights and regards of others is obtuse. This disposition is the very reverse of backwardness. It is called "freshness." And although the term grates harshly upon the sensitive, and perhaps I should have said sensible, ear, for which it is not intended, it has no significance with the subject of the malady. I mean that some students make themselves obnoxious and the subjects of ridicule, and in extreme cases, of more convincing disrespect, from their lack of respectful address and consideration of the rights and feelings of their fellows.

However, I hope for the coming term that good-will and pleasantness will alway proceed from those of the first year to their seniors and to one another. And I believe in such cases that the same will be returned. Be real. Be honest, fair and considerate, and remember unto performance the Golden Rule. We have entered upon grand professions. Will the smooth running of our minds in mathematical grooves fit us for such professions? No. We may become well-trained in mathematical reasoning and yet be no credit to ourselves or our profession. What should we be? Men—liberal in thought, education, and sympathy for our fellows, honoring truth and fairness in every act, dealing honorably with all men, as well as being educated and proficient in the requirements of our work.

We have reason to think well of our espoused professions. Take a glimpse at their advancement during the last few years. See that flying steel monster, carrying in his wake a train of handsome coaches, whose speed and comfort compare so strikingly with the stage coach of a few years ago! Observe how swiftly it moves, now skimming over the plain, now rising over lofty hills and deep gorges, and again darting through and beneath them, and connecting by easy transit one ocean with another—even passing with ease and rapidity beneath rivers, and connecting the commercial enterprise and industry of nations.

See even the arrows of the heavens are giving light to our streets and shops. They propel our street-cars. They flash a message beneath the ocean, and around the globe. They carry even our voices to ears miles away, and the wasting energy of nature for the economic purposes of man.

Compare the useful and comfort-producing machinery of to-day with that of fifty years ago. Ride with safety, comfort and convenience in that modern city of steel, the ocean steamship, and look down upon the dugout of the aborigines.

See the graceful, yet sometimes appalling, masses of steel that unite the banks of chasms and rivers deep and wide. Compare the sanitary condition of the houses and towns of to-day with those agone, and the elegance of proportion and design of modern true architecture.

Shall we, who have the rich heritage of the thought and experience of the past, be of less use than our predecessors? We ought not How many of us aspire to the thoroughness necessary to success in any cause?

What has been said of law, that "There is always room at the top," is also true for engineers and architects.

Perhaps none that graduate from this school will ever rise to the height of his profession, and surprise the world with his skill. But who knows? It is not impossible. One thing is necessary—thoroughness. Therefore let us so apply ourselves to the work of our cause, and to the auxiliary work of our Society, that we may be alike a credit to our profession and the school from which we graduate. For, let us not think that the reputation and work of this school has reached its height, but rather by our individual and united effort second the desire and work of the Council to make this school second to none in America, and the pride of our Canadian profession.

Now, let us turn our attention to a resumé of our Society. As many of you know, it was organized in the spring of 1885, to supply a real need in the student life and study for some place of general gathering to ripen acquaintance and friendship, to exchange ideas and methods, for systematic reading and discussion, to make students more familiar with the work and practice of their profession, by showing the relation of the more or less abstract work of the school with the concrete work of the practising student.

From its start up to the end of the term of 1887-8, the membership was small, but the Society had for its president Prof. Galbraith, who directed and encouraged its members in doing good and permanent work. Constitution and rules were drafted, periodicals and magazines on the subjects of engineering, architecture, and sanitation, were obtained, papers were read and discussed, printed copies of which you may find in our library. At the end of this time Prof. Galbraith considered the Society self-supporting, and advised the election of a student as president. Accordingly Mr. H. E. T. Haultain, who is now chief engineer in a tin mine in Bohemia, and who is an able and pushing young man, was chosen. The Society, by his help, made good progress—a good library was established, the periodicals and magazines were continued and increased, and contributions from graduates were solicited and obtained, which together with good papers prepared by the students were printed in illustrated and interesting form, copies of which were presented to you at the beginning of this term.

During the past year the Society made good progress with Mr. J. A. Duff, B.A., president, and Mr. T. R. Deacon, who is now our vice-president, as secretary-treasurer. Library rules were made, the constitution was amended, and a more commodious room was obtained for the library. The office of secretary-treasurer, which had become heavy, was divided the office of special students' representative was discontinued, and many valuable papers were read during the year, some of which you will find in the pamphlet presented to you. And among the indirect but important doings of last year was the starting of a branch of the Canadian Society of Civil Engineers.

By the burning of the University on the 14th of last February, at the time of our annual conversazione and engineering exhibit, we sustained many losses of papers, models, instruments, and decorations; but we are pleased to say that our Society, in common with the other societies, was able to clear itself, and now stands ready for the performance of good work during the coming year.

And now we face our position. Shall we accept the labor and rewards of the work of our predecessors in form only, and allow the Society, which we received in a healthy, growing state, to dwindle and die amidst the dense foliage of its environment, whilst the many societies that surround it have considered it a live and growing competitor? Shall we be content in doing less than they? They have nurtured this Society in its weakest days, and have implanted it in the soil of this school. Shall we not continue its supporters?

All who have taken an interest in this Society have by it been benefited just in proportion to their interest and work; hence for your own good and that of the Society, we say become active members at once. The Society will be the better of you, and you of the Society.

From the vigorous growth of the branches of this school, there may arise a desire for a separation of this Society into branches; but since one of the main objects of the Society is to broaden the mind of the student, and acquaint him not only with the work and practice of his profession, but also with its bearings upon and relation to other professions to which it is closely connected in practice; and since civil engineering, mechanical engineering and architecture bear such relations, and the mathematics of each are so alike, that papers written on any one line may be readily understood and discussed by the students of the others, it is of mutual benefit that we maintain our present vigorous unity, and the more intimate that unity the better for all.

Our constitution states that "The objects of this Society shall be (*a*) the encouragement of original research in the science of engineering; (*b*) the preservation of such research; (*c*) the dissemination of such research among its members; and (*d*) the cultivation of a spirit of mutual assistance among the members of the Society in the practise of the profession of engineering."

Now, while these may have been the primary objects of the Society, they are not now the sole purpose of this institution.

This Society may, by its educational influence and solicitation of papers, encourage original research by graduates; but such research by students is, from the present state of the science, our undeveloped minds, and the extent of our studies here, inadvisable. A greater benefit to the undergraduate members is the free, voluntary, and interested thought, practised in preparing a paper, in discussing it, or in reading an engineering or architectural article.

Here among the students original research, so far as the benefit to the science itself is concerned, would be too much like the small boy hunting through a menagerie for a rare animal not known to the owners of the show; he might find a shylikulie, but Professor Chapman would surprise him by giving its real name, its family relation and history, from away back in the rocky past.

Yet original research, even by the students, is not to be despised, for it strengthens his reasoning and fixes the practice of independent thought, and the result of his efforts firmly within his mind.

What we need here is not so much originality as the seeing of new or old thoughts in new aspects and interesting forms.

We have in our course of study thoughts, reasonings, and facts, assorted, classified, and concise. Their very conciseness has deprived them of their beauty and attractiveness, and cut them down until but the framework or bones remain.

A part of the effective work of this Society is the shaking up of these dry bones into form, that we may see the better their use and relation to one another, and their actual necessity to support the flesh of detailed practice; the muscles of clear and active thought, the steady stride of ability, the full, sleek coat of sound sense from wide knowledge, and the spirit of courage and success, that will win the full measure of the meal of approbation, and of the oat whose kernel is golden.

As the veterinary student, reading by the help of the bones of his subject, is improved and encouraged by the sight of and acquaintance with his living subject; so we like to see our subject in life-like form, inspecting him from all sides and becoming used to his disposition and habits, that when he carries us proudly out from these walls, we may with confidence ride into the world and compare favorably with our fellows.

The last clause of the objects of our Society, as given in our constitution, I endorse heartily, that is, "The encouragement of mutual assistance among the members."

Everywhere around us, in labor and capital, profession and art, politics and religion, we find organization, circle within circle, as molecules, composed of atoms of mutual affinities, combine to make up the composite whole ; so we, if we wish either in student life and pursuits here or in the practise of our professions to occupy a place of security and advantage, and not be dissipated though the interstices as a bye-product of other organizations—we must support each other and uphold our Society union, for in union there is strength.

All matter is capable of receiving and transmitting energy in some form from and to other matter; so we, in like manner, are susceptible of receiving and imparting education from one to another, not only by words and acts, but also through the subtle agent of influence. Now, as success in our profession depends upon the knowledge of our work, let us cultivate and retain the society and educational influence of our fellows, and in no way can we do this better than by organized society work.

On entering the practice of our profession, we will be confronted by the application of our theory to actual practice. Shall we be able to make our way clear, or shall we be confounded? This will depend upon our knowledge of the ways and methods of actual practice. Where and how can we best keep in touch with the practice of our study whilst students here? By the preparation, reading and discussion of papers before the Society, by the reading of live engineering and architectural news, such as our library affords.

On account of your superior opportunities for education and of your profession, you will not only in the discharge of our duties, but as citizens, be called upon to take active parts, and give opinions in matters that will require prompt action, good judgment, and a ready and clear explanation to others that will oppose you on every side. Can you conceive of anything better suited to your development in these lines, and at the same time within the range of pleasant possibilities, whilst students here, than the duties and privileges that our Society involves and affords?

And lastly, look at our library. I shall not dwell upon the advantages of its free use ; the books, new and old, that it contains; its models and sketches; its live scientific news, to which are to be added the books now in the University library that relate to our subjects, which will make it more valuable and interesting. The conditions of these additions have not been arranged. This, together with changing rules, will be one of the important things that will come before the General Committee and this Society early this term.

And now, regarding interesting material for these meetings, it is a part of the duty of the General Committee to arrange work for the meetings, and yours to second them in their endeavor. One of these will call upon each of you to render something. If they miss you, volunteer. Will you? None need refuse. We have had in the past, I might say, equally good papers from first, second, and third year students. Very few of us but know something of general interest that others do not, the preparation and giving of which would improve the giver and instruct the others. Our offering need not attempt to exhaust the subject of which it treats. This is not expected. If we even cannot do as well by trying as others, let not that be to our discredit, but his who could but would not.

Our corresponding-secretary, Mr. G. E. Sylvester, has been instructed by your General Committee to correspond with Dr. P. H. Bryce, Secretary of the Provincial Board of Health, who has volunteered a lecture upon a very interesting subject at one of our early meetings. He will also correspond with our graduate members, and invite papers from them for our Society. He has also short letters from each of our two past presidents, that he will read at your convenience.

And now we wish to express loyalty to the charge of our predecessors' work and desires, compatible with the best interests of the Society and the good of the members and students; deference and honor to the merits and opinions of teachers, members and students; fairness in all dealing, and confidence in the judgment and support of our General Committee and yourselves in maintaining the usefulness and reputation of this, our Society, for this year and the years to follow.

J. K. ROBINSON.

# UNDERGROUND WATERS AS SOURCES OF PUBLIC WATER SUPPLIES IN ONTARIO.

By Peter H. Bryce, M.A., M.D.,
*Secretary Provincial Board of Haalth.*

*Mr. Chairman and Gentlemen of the Engineering Society*,—When we observe the remarkable situation of Old Canada, but notably of Ontario, in its relations to the bodies of fresh water constituting the Great Lakes, and note the configuration of the surface of the country contributing to the supply of these great lakes, we are naturally surprised to see that, at some point or other, the whole of these immense watersheds contribute their drainage to some one or other of these great lakes, as completely as if Ontario were an island and the great lakes the surrounding ocean. Remembering, too, the comparatively small distance north and south that the various watersheds of the great lakes occupy from the points at which their waters are delivered into some particular lake reservoir, we are surprised to see how comparatively short is the course of any individual river, even the longest, the Ottawa. There result from these conditions two remarkable phenomena, without, I think, any parallel on the face of the globe. The first of these is the unusual exposure of the sources of these streams to the effects due to the destruction of their protective forests. Already, as will be noticed, all the protection is gone from the head waters of the rivers of Western Ontario. Follow them along, starting with the Lake Simcoe and Severn supply, and note them till we have reached the Humber and Rouge. Where are the Nottawasaga, the Sydenham, the Maitland, the Saugeen, the Thames, the Irvine and Grand, and the many creeks, as Stoney creek, Twenty-mile creek, etc., flowing into Lake Ontario from the Niagara escarpment? Even in the brief history of fifty years since settlement properly began many of them remain as little more than memories, unless when the sudden floods of some autumnal storm fill them almost as suddenly as does a storm among the rocky scaurs of the mountains of Scotland. But note again the watershed, starting at the Upper Ottawa and follow along the undulating table land, for it is nothing more, of the Laurentides, till where the waters run toward Lake Nipissing and the Georgian Bay, then skirting along the line of the C. P. R. till Port Arthur is reached, and it will be noticed how really short are the courses of the streams flowing into Lake Superior or the Georgian Bay. To many who have been on exploring or surveying parties in these northern wilds, it may appear that whatever may have happened in Western Ontario cannot happen in the case of this rocky district; but we have only to listen to the warnings given by those who have studied the subject, such as Mr. R. Little, of Montreal, and other members of the American Forestry Association, to realize how the same process of destruction is going on at a rate in this region incomparably more rapid than that which went on in Central Ontario. Already we learn from lumbermen that the great pine limits of this area are enormously reduced, while personal observations, made in various portions of the region, too surely indicate that deforesting by vandal acts and fires is rapidly denuding these areas of the natural protection to the sources of the feeders of our great lakes.

The second remarkable phenomenon is, that the natural basins into which these numerous watersheds pour their waters constitute so many basins which, narrowed at their outlets, serve to maintain an equilibrium of waters in proportion to the shallowness of their outlets and to the evaporation which takes place from their surface. The preservation of these waters is remarkable in both these respects. For instance: the outlet of Lake Superior is comparatively a small stream discharging but little more than some of the tributaries of the lake, while the temperature of the lake is relatively so low, and its depth so great, that the relative evaporation from its surface during the short season of summer must be infinitely less proportionately than from shallow, smaller reservoirs, whose surface would be in proportion much greater were the volume of water the same. To illustrate the manner in which the low temperature of these lakes is maintained, it may be mentioned that the greatest depth of Lake Superior is given at 895 feet, and that of Huron 1,000 feet. Now it will be apparent to all that, apart from the consideration of the supply to these lakes or the rain falling on their surfaces, it will be a very important factor in the maintenance of their levels to enquire whether the waters flowing into them have been, or are likely to be, so altered in their annual amounts as to create notable differences in their levels, assuming, as seems to have been proven by calculations made of the rainfall, registered at the Toronto observatory, during a period extending over forty years, that the annual precipitation of moisture does not greatly vary over a series of years. It might, at first sight, appear that the lake levels are not likely to be altered, but a closer enquiry reveals the fact that an actual decrease in lake levels, at some points, at any rate, has taken place. I was recently informed by a close observer that the fall at Kincardine at some seasons of the year is at least four feet. That this should take place at certain seasons of the year seems inevitable, if we consider some of the facts in regard to the decrease in the volume of water observed in the streams of some of the older portions of the Province. Thus at the time I made a study of the rainfall of semi-decades from 1840 to 1845, to 1870 to 1875, I found great variations in the rainfall of the later spring and summer months to have taken place. Thus March has remained the same, while in April I found a decrease of not more than half an inch ; a decrease that increases with each month until September. Thus :—

| | April, May, June. | July, Aug., Sept. |
|---|---|---|
| 1840-44 | 48.55 inches. | 68.101 inches. |
| 1850-54 | 40.195 “ | 48.625 “ |
| 1860-64 | 32.742 “ | 45.617 “ |
| 1870-74 | 34.670 “ | 35.14 “ |

Or take May and we have :—

| | |
|---|---|
| 1840-44 | 15.015 “ |
| 1850-54 | 13.675 “ |
| 1860-64 | 14.055 “ |
| 1870-74 | 8.64 “ |

When it is remembered that at a lakeside station, as Toronto, influences which create such striking differences are less than at more inland and upland localities, as those of the central plateau and oak ridges, we may affirm that their effects at those points, whence so many of the rivers of the Province take their origin, would be at least as great as at Toronto. Again, while it might be said that, in a region such as the Laurentides of the Muskoka district, the numerous small lakes act as so many reservoirs containing the waters which flow into them from innumerable streams, yet if we consider that such an area denuded of its forests presents unlimited stretches of bare rock where the virgin soil has been destroyed by fire, or wasted away by erosion, we can very well understand that the spring rains and melting snows are yearly more rapidly swept into these basins, and thence into the great lakes, instead of being stored up in the humus and leaf-mould of the hillsides and valleys, thereby producing as yet, of course in less degrees, the same summer losses to the streams which we know have taken place in the streams of Central and Western Ontario.

Reverting now to the special subject we have proposed for discussion, we can understand how important is the bearing of these facts, not only on the question of underground waters as a source of public water supply, but also upon that other of paramount importance, namely, the retention in the soil of such stores of water as are required in the successful prosecution of agriculture. Leaving the latter out of consideration for the present, it may appear to some that so long as our great lakes remain as unlimited reservoirs, there need be no anxiety as to our obtaining abundant supplies of water for public purposes. This might be true if all our cities, towns and villages were situated on the shores of some one of these great lakes ; but unfortunately all are not. But even if they were, their growth and the methods of disposal of their sewage at present in vogue force upon us the disagreeable fact that we have no guarantee that these inexhaustible sources of supply will remain unpolluted to the extent of their yielding supplies of water beyond question in the matter of purity. Already we have presages of evil. On the River St. Clair, we have, growing up on both sides, large towns, both taking water from and pouring sewage into the same stream. On the Detroit river, Windsor is already having cause to doubt the purity of her supply with Detroit and Walkerville polluting the river above ; and only last week the submission of a scheme to the Provincial Board for supplying Niagara-on-the-Lake with public water from the river, revealed the fact that chemical analysis found the water to be second class in the matter of purity, and by no means equal to Lake Ontario water at the bell-buoy outside Toronto island, as shown by analysis several years ago. Very recent analysis has shown Toronto water to be depreciating in quality. Thus :—

| | Niagara River at Niagara-on-the-Lake. In parts per million. | Lake Ontario at bell-buoy. In parts per million. |
|---|---|---|
| Chlorine | 2.00 | 3.00 |
| Free ammonia | 0.04 | none |
| Albumenoid ammonia | 0.12 | 0.02 |
| Oxygen absorbed in 15 min | 0.24 | 0.16 |
| Oxygen absorbed in 4 hrs | 0.74 | 0.508 |
| Total solids | 133.00 | 124.00 |
| Loss on ignition | 48.00 | |

While it might be unfair to charge this pollution of Niagara river water wholly to sewage, yet the fact remains that Buffalo, Tonawanda and Niagara Falls towns, on both sides of the river are polluting the river. Evidently the rapids, the falls and the whirlpool are not all sufficient for purifying purposes. What the fate of Toronto's water supply will be in case the scheme of a trunk sewer discharging off Victoria Park be carried out remains to be seen. When, however, it is remembered that our inland towns, situated on streams of yearly diminishing volume, have shortly, and many have already begun, to exploit local sources for their supply, we must recognize how important becomes this question of underground waters for public purposes. While the problem of obtaining these waters for drinking purposes is not a new one, since up to the present they have been practically the sole source of our supply as taken from wells, yet there can be no doubt that the popular belief that these wells are due to the happy accident of striking some isolated spring prevails very generally. Manifestly, therefore, it is important to those of us who have to deal with these problems of public water supplies to enquire to what extent we may look to these underground waters for a solution of the difficulty of obtaining public water supplies for at least our inland towns. That their volume is enormous may be concluded from our knowledge that where surfaces consist of leaf-mould, humus, or sands and gravels, an amount of water roughly calculated as at least equal to that which flows from the surface into the streams and rivers penetrates the soil, and passing downward is either stored up in subterranean reservoirs or flows gradually along the hidden inclined strata, appearing here and there again, where the strata have been denuded, as springs. Indeed, as regards their amount, we may say that beneath the surface of the gathering grounds, creating these immense reservoirs of our inland lakes, are stored as great quantities of water as those in our lakes, less whatever differences evaporation and the rainfalls directly upon the latter may make. It is, perhaps, difficult for us to at once realize this, but if we consider for a moment the nature of the springs which we see cropping out on many a hillside, we may not be surprised at the statement. A spring appearing as a small stream and flowing at the rate of ten gallons a minute gives a 24-hour flow of 14,400 gallons. How small a stream this means is best realized when we remember that a three-inch tile running full at a dip of one in fifty gives a 24-hour flow of over 90,000 gallons. If we further remember that with an annual rainfall of 30 inches, of which 15 may be said to sink into the soil, the amount of water which an acre would yield will keep a spring yielding the above daily amount flowing for nearly 23 successive days, or for nearly a month's time we can understand what it means to have an upland of miles in extent dipping towards some valley eroded transversely to the strata and consisting of an impervious clay below and a permeable soil of gravel above. It here becomes important that we enquire into the conditions upon which the storage of underground water depends generally, but especially into the conditions which prevail in Ontario. It will be remembered that we have bordering the Province along the east and north the gneissoid Laurentian rocks, and that super-imposed on this, and following each other in regular order, the series of Silurian and Devonian rocks, mostly of compact limestone or calcareous shale, till the River St. Clair is reached. In central Western Ontario these have an elevation of over a thousand feet, and from this height the strata dip more or less regularly in every direction. All evidence goes to show that at the close of the glacial period these rocks were covered with a body of fresh water, and that materials from their disintegrated surfaces were gradually deposited in a more or less quiet inland sea in an order depending upon their character. In the shallower waters the heavier materials of boulders and gravels sank to the bottom or were thrown up on the shores or deposited on shallow beaches, many of which can be seen in the highlands of Wellington, Perth, and Huron counties. Mingling with these deposited drift materials would of course be certain proportions of clay, and indeed these deeper boulder strata, and in these districts highly argillaceous strata in the deeper waters, were deposited in a state of great regularity and in a state of great purity; but even under these beds of clay are to be found in most instances, as throughout Kent, Lambton, and Essex, a thin stratum usually of from one to two inches of fine gravel, with extremely fine grained sand above it. The latter over some parts of the oil region is black in color and forms the reservoir for water and in some places gas. As the waters receded further and these so-called Erie clays came into shallower water, they became overlaid with strata of finer gravels and sand in less regular order, similarly as on the uplands intermixed with clay in varying proportions, thereby giving us the warmer loams of Waterloo, Oxford, Brant, Norfolk, and Elgin, as also in some portions bands of the so-called Saugeen clay. To the west, north-west, north-east, and east of Toronto, running from the Niagara escarpment to the gneissoid rock, again we have, according to the height, these same strata more or less regularly appearing, while they are not wholly absent from the surface of the gneiss, although it is mostly in the smaller lake basins or river valleys that they can be said to be of any extent.

Inasmuch as the rainfall of any region in Ontario may for practical purposes be considered as averaging a given amount, say 30 inches as snow and rain annually, it must become apparent that it will depend upon the nature and condition, as also upon the inclination of the surface strata, what proportion of this rainfall will sink into the soil to become the source of these underground waters that we have been discussing. It will further be apparent that the order of arrangement of pervious and impervious beds, as well as the thickness of strata, must become essential factors in considering the amount and constancy of any underground supply. Thus, to illustrate this we have only to refer to the variation in the prevalent depth at which the water of ordinary wells is obtained in different sections. For instance, in Ontario, in the flat country around Chatham and Windsor, shallow wells of ten to twelve feet are most common, these being supplied only from the soakage from the black humic loams lying on the top of practically impervious clays, and becoming dry when the dry season comes on. Further east, as around London, Woodstock, etc., abundant waters for household purposes are found in sands and gravels lying upon the top of the clay. Similar variations can be pointed out as occurring in closely contiguous districts, and nowhere are they better seen than around Toronto. While, however, these shallow wells may afford in many instances abundant supplies for the purposes for which they are intended, it is apparent that inasmuch as the area of their gathering grounds is very limited, their supplies can easily be exhausted. Let the surface be locally eroded by a water-course and we find, especially in the sands and gravels, springs cropping out, creating local bogs, etc., and presenting exactly the same general conditions as would a spring far down the declivity of a deeply eroded valley, except that in the first case a summer drought would cause it to dry up, while in the latter the flow of water would not be altered by one season's drought. *

The following cuts will serve to illustrate various conditions which occur in the deposition of soils and rock material, and upon which we may expect to find the abundance of water in any locality dependent:—

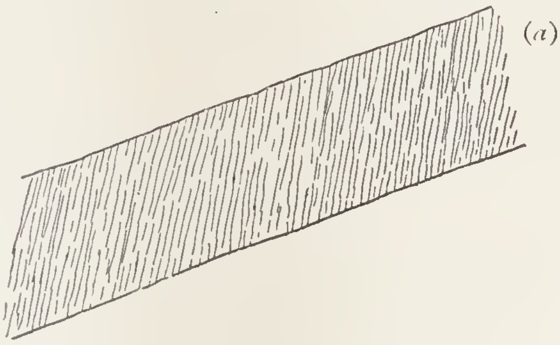

FIG. 1.
Impermeable clay, Erie clays (Logan).

Such soil has great retentiveness, or its hygroscopic character is very high, reaching 75 per cent. of its own volume, or may hold three-fourths of its own volume of water. With impermeable clays forming hillsides, rain will flow rapidly from the surface; but where this clay has a level surface, the land will be wet, whether on high plateau or in river bottom.

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* The celebrated French engineer, Durand Claye, has classified springs into: First, springs from impermeable layers. There is no water-layer, properly speaking, in soils of this character; the place of springs in this case is the surface of the country, and as the surface flow carries away the great part of the rainfall, these springs are always very small. Second, springs from layers entirely permeable. Here the absorbed waters descend in continuous or discontinuous layers towards the deepest valleys. The springs are found in the humid and even peaty plains which carpet the bottoms of these great valleys. We find them at the bottom of bogs, along water-courses, while the less deep valleys, the hillsides and plateaus remain dry all the season. Springs of this class are far apart and have considerable yield. This class of springs exists in the soils of this Province, but not to the same extent as those of France, in the oolitic limestones of Burgundy, the white chalks of Champagne, of Normandy, and in tertiary limestones. It is to this class belong the springs which supply Paris, and these are not always perennial. Third, springs from permeable or moderately permeable layers, upon impermeable beds. Following the plain of contact of permeable and impermeable layers, there is established a water level on the side of the hill as well as in the bottom of valleys. These springs are generally numerous and consequently of a small flow. This class is especially characteristic of the strata which are superimposed upon the rocks of the Province of Ontario. Fourth, artesian springs, or those which flow from an imprisoned water layer between two impermeable stata and flowing forth from a boring or well.

Into it rain will very gradually penetrate. Where impermeable clay has a locally denuded surface (as in Fig. 3 at 1), forming local depressions or basins, vegetable deposits and fresh water plants are largely present, creating waters often unwholesome as public supplies.

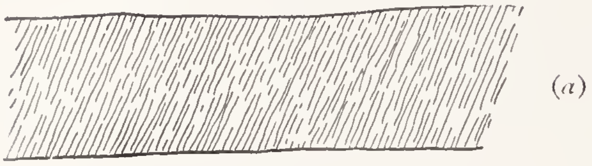


FIG. 2.

In retentive clays, cultivation, deposits of litter and leaf-mould, straw, roots of trees and grasses, and frost, all increase perviousness of surface to rain and air by loosening the soil.

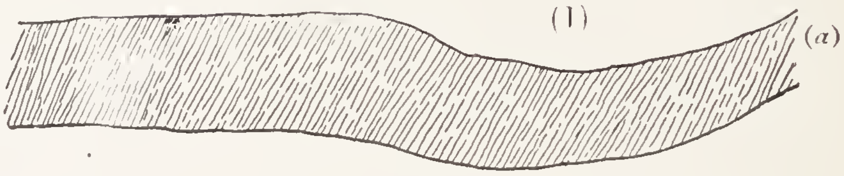


FIG. 3.

Leaf mould, while very pervious to rain, has at the same time great capacity for moisture. A moss has a small capacity for retaining moisture.

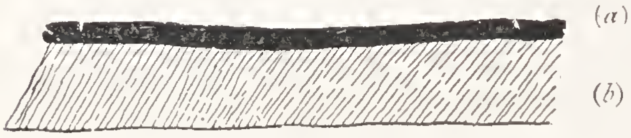


FIG. 4.

Leaf mould or virgin soil at top of clay.

The amounts in percentage of volume which various leaf litter or mould can contain, according to Wollny, are:—

| Depth of litter. | Oak leaves. | Spruce leaves. |
|---|---|---|
| Two inches.... ............... | 50.11% | 38.98% |
| Eight inches....... ............. | 53.09 | 41.65 |

Permeable sands and gravels receive and retain a very large proportion of the rain which falls upon them. At the London Asylum sewage farm six inches of water from the open ditches will frequently have disappeared in twenty-four hours. The capacity of such sand for retaining moisture is small in the above locality. Not more than 15 per cent. of the volume remains in the soil, but passes downward until it reaches an impermeable stratum. Such soils, when of sharp sand (pulverized quartz, gneiss, etc.), are the

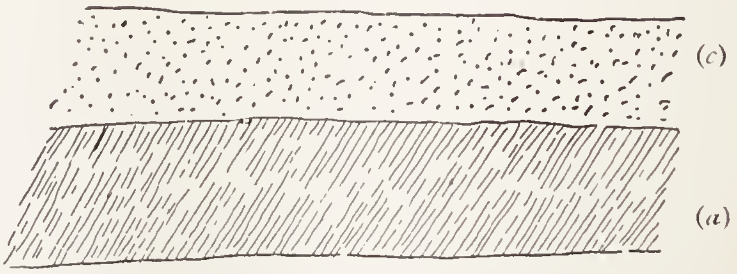


FIG. 5.

Permeable sands and gravels (overlying unpervious clay) as in Waterloo, Oxford, Brant counties and Oak Ridges.

most favorable for purposes of a sewage farm, allowing of the passage of the largest amounts of water, leaving organic matter behind in the upper film of the soil, where it is rapidly destroyed by nitrification.

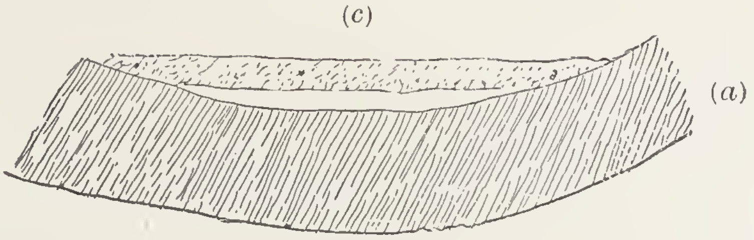


FIG. 6.

Sandlayer in denuded valley on top of clay. It occurs in many places as a common source of many surface wells, and even, when over large areas, of artesian water.

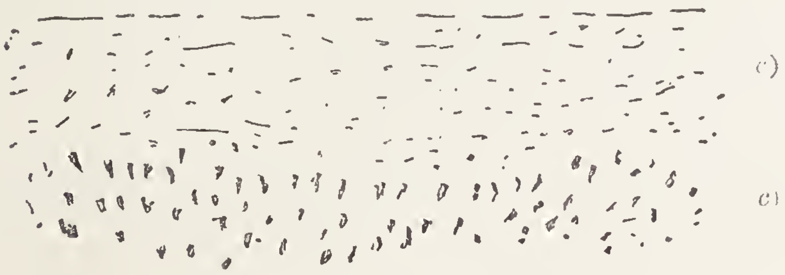


FIG. 7.

Deep sand and gravel strata, finer above, overlying boulder gravels. These soils over extensive areas become the great deep water reservoirs, the sources of large springs, and, with favorable deep strata, of artesian waters of large supply.

In such cases, as in No. 8, the rain falling upon the permeable soil at (*c*) passes along the surface of the impermeable bed (*d*) and will be found at varying depths from the surface at different points.

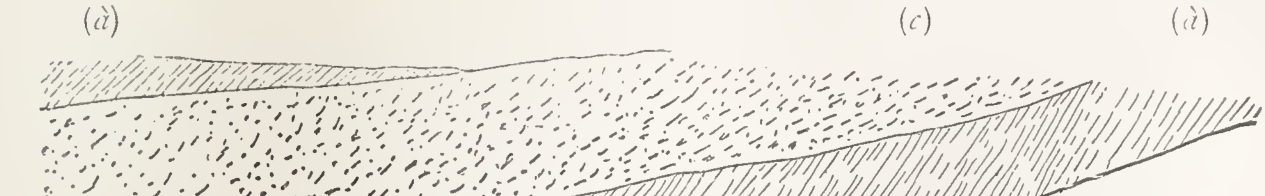


FIG. 8.

Permeable sands and gravels lying between two impermeable beds of clay, with clay above and rock below. Such a condition occurs in Western Ontario from London westward.

As shown in Fig. 9, it will be seen that the permeable strata receive the rainfall and store it as a subterranean lake reservoir, giving an artesian supply in proportion to the extent of the synclinal basin, to the extent of the permeable beds at the surface and to the angle of the dip of the underlying impermeable clay or rock stratum.

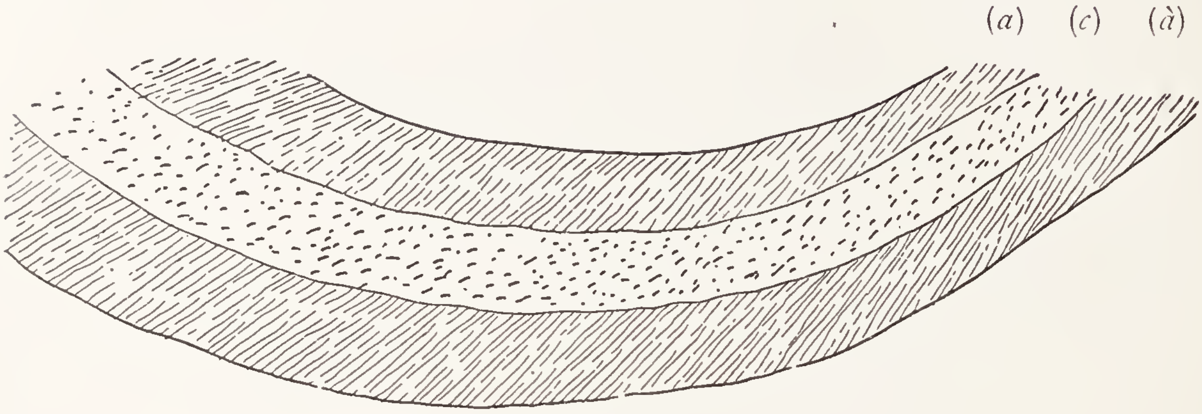


FIG. 9.

Permeable sands and gravels in a basin between impermeable beds. This condition is present in many places in Ontario, notably in the synclinal between London and the River St. Clair at Chatham, Leamington, etc.

In such instances the rainfall may disappear in faults and fissures, or be diverted in various directions according to the varying dip of rock strata. See Fig. 10.

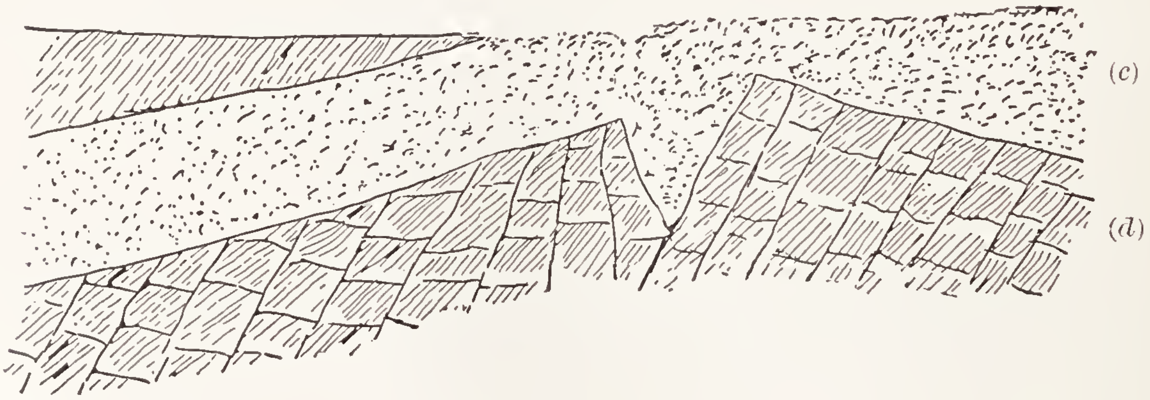


FIG. 10.

Permeable sands and gravels deposited upon underlying rock, folded and forming an anticlinal with a fault and strata at different angles. Such instances occur in the Alleghanies and other mountain ranges, and create local difficulties in obtaining underground supplies.

As springs are nothing more than surface indications of the existence of underground streams, they become interesting as an index of the locality of such underground streams, and of their volume. We have already referred to the depth of these underground streams as being to some extent a measure of their perennial character. Remembering the source of their supply, we naturally expect variations in the amount of the flow of a spring at different seasons of the year. These variations follow a movement consecutive to that of the rain and subterranean streams.

Durand Claye in a table gives the rainfall and flow of the streams forming the River Vanne, which supplies the city of Paris, thus :—

| Springs of the Vanne. | 1869. | |
|---|---|---|
| | Rain. | Flow. |
| | millimetres. | litres per second. |
| January | 20 | 1190 |
| February | 38 | 1103 |
| March | 65 | 1232 |
| April | 24 | 1278 |
| May | 131 | 1195 |
| June | 55 | 1150 |
| July | 42 | 1057 |
| August | 19 | 972 |
| September | 60 | 818 |
| October | 35 | 818 |
| November | 72 | 807 |
| December | 33 | 839 |
| | 594 | 1057 |

In this connection Durand Claye points out by a comparison of the constancy of the source of the river Dhuis, as compared with that of the Vanne, that the deep springs are much less variable in their flow than those from shallow water zones.

Having discussed some of the principal points in the origin of springs and underground water courses, it will be proper for us now to consider them in their application to this Province. Unfortunately we have no literature whatever bearing upon this subject, and any investigations of the subject have hitherto been of a most partial character. The Geological Survey has, I understand, been collecting data with regard to borings in different parts of the province, but as only related to salt, oil, and gas. The most that we know is gathered from towns and villages here and there which have utilised some local source for fire purposes, and in some instances for domestic purposes. Owen Sound obtains an abundant supply from a large spring flowing high up out of the hillside from a fissured limestone stratum of the Niagara formation. Kincardine obtains at a depth of 420 feet (also at a depth of 240 probably) a splendid artesian flow, while on the hillside numerous springs crop out supplied by waters flowing along a hard-pan 15, 20, and 30 feet below the town, the present source of wells.

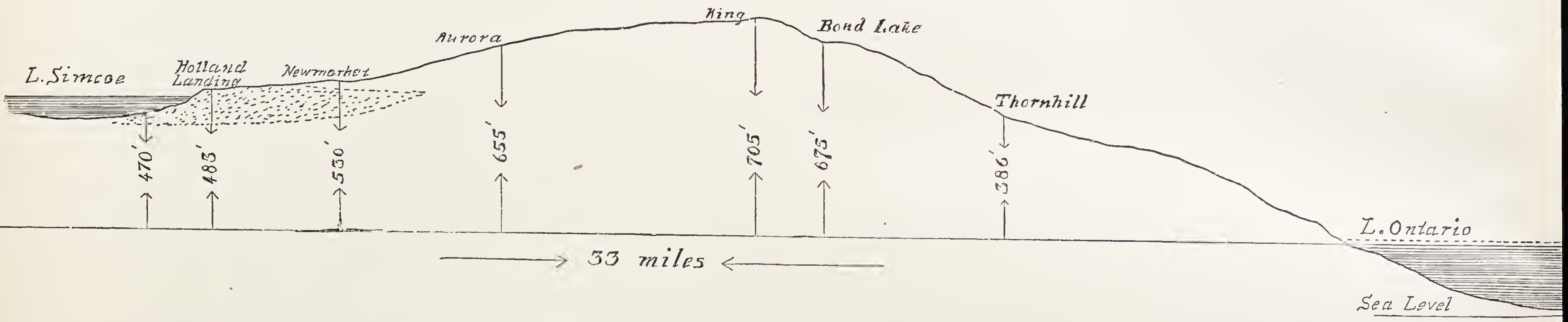
Goderich obtains a daily supply of nearly 2,000,000 gallons from six eight-inch borings down about 240 feet, within a quarter of an acre of ground. Walkerton is obtaining from springs situated on a hillside enough for a supply by gravitation. Various places in Lambton County, as about Forest and in Warwick township, obtain from a sand layer some 75 feet deep artesian water coming to within 20 feet of the surface. In Chatham and vicinity are a number of artesian wells coming to the surface, or nearly so, from a depth of 64 feet. At Kingsville, in Essex, some borings down to the rock have resulted in no water, while others have yielded an abundant supply of sulphurous water. Leamington is being supplied by artesian water from 55 feet deep, while at St. Thomas they have obtained at the court house a fine supply and at other points sulphurous water as artesian supply by borings. Springs out-cropping up the valley of Kettle creek at St. Thomas, flowing from the superficial sands and gravels, are likely to be developed finally for a public supply. Around London, borings to the rock have supplied sulphurous artesian water in some instances, and in others waters of a perfect character. The city of London is obtaining an abundant supply of splendid water from springs which appeared at the surface of the hillside along the bank of the Thames, some three miles below the city, and the supply has been enormously developed by simply running a gallery along the hard-pan for half a mile or so and conducting the water to the small pumping basin. These waters are gathered on the higher grounds which to the south of this point rise to nearly 200 feet, and are formed largely of pervious sands and gravels. No tests that I am aware of have been made of the variations of the flow of these magnificent springs. At St. Marys, and I believe at Woodstock, artesian water is obtained. Springs abound above Berlin, a public water supply being there obtained from them, while Guelph, too, is supplied mainly by springs. At Tilsonburg is found artesian water, while at Dunnville and about Jarvis in Haldimand County artesian water is obtained within a few feet of the surface. Brantford has a magnificent supply, obtained from perforated pipes laid on the hard-pan 13 feet under the sand and gravel of the island in the river. Niagara-on-the-Lake has numerous springs which are now being developed, with a view to a public supply. St. Catharines gets the supply from springs forming Decew's creek, flowing from the Niagara limestone mountain south of the city. About Toronto, no true artesian well water has been, so far as I know, obtained, although Mayor St. Leger has obtained at his residence on Bloor Street, near High Park gates, water rising, in a six inch boring, 189 feet deep, to within 40 feet of the surface. Borings down to the rock under the clay at the Mimico new asylum buildings obtained no water, nor yet when over 1,000 feet of rock had been bored. Curiously enough artesian water is obtained at Newmarket, situated on the north side of the Oak Ridges, while Barrie and Orillia both have artesian water, at depths of 100 to 150 feet. Smith's Falls in the east has water, partly artesian, rising in borings in the rock. Penetang and Markham are developing springs to obtain public supplies, while most curious of all Sundridge, on the Laurentides, some fifty miles south of North Bay, is obtaining abundant supplies of artesian waters at a depth of 100 feet.

Such is, in the briefest possible way, a statement from memory of the underground sources of public or private supply which have been developed in different parts of the province. They clearly point to the extreme importance of the problem which lies before you future engineers in the matter of supplying our inland towns with water. It is by no means improbable that the problem of applying to these underground sources for supplying large cities in Ontario will be discussed in the near future. Brooklyn, N.Y., is now supplied with 30,000,000 gallons a day from pipes driven into a sand stratum within twenty feet of the surface, and so abundant is the supply under the level surface of Long Island, only a few feet above the sea-level, that I personally saw from 125 2-inch pipes coupled together within an area of one-eighth of an acre over four millions being pumped day after day.

I may be pardoned for referring in this connection to the possibility of obtaining for Toronto a public supply from these underground sources. Here we are hampered again by a lack of data from speaking very positively, and yet there is a large amount of information regarding the topographical and surface physical conditions which may serve as a basis for discussion. We usually speak of Lake Ontario as being 247 feet above sea level, while the strata rise towards the north till at King Station a height of over 900 feet is reached, thence descending till Lake Simcoe is reached at 717 feet above sea level. We all remember, too, that running south, some easterly and some westerly, are a number of valleys, as those of the branches of the Don and various other creeks, some dipping toward the valley of the Humber, and others toward the Rouge. From what has been already said regarding the law governing the deposition of the post-glacial deposits, we may expect to find, what at most points is found, that over the rock strata of this region the Erie clays have been deposited with much regularity, over probably, as in the west, a thin layer of sand and gravel, and that over them but less regularly sands and gravels varying in their calcareous and argillaceous character—and therefore in their permeability—have been deposited. Were we to assume for a moment that no variations have taken place in the level of the underlying rock and its superimposed clays, sands, and gravels, it would be an easy thing for us, with a known rainfall, the degree of permeability of the strata, and their inclination to dip southward, to calculate with much precision the probabilities of obtaining a given amount of water at any point. Unfortunately for the calculation, however, deep erosions have taken place in these various deposits, and so have been formed river valleys dependent for their water supplies upon springs of the third class of Durand Claye.

Another class of erosions exists in the shape of depressions, creating small lake basins. From the survey of McAlpine and Tully, we find that the whole of those forming the so-called Bond Lake system have an area of 462 acres and a watershed of 7,600. From calculations made on the basis of this area of 7,600 acres receiving 30 inches of rainfall, half of which soaks into the soil, it would hold a possible supply of water equal to 20,000,000 gallons for 135 successive days. Of course a certain loss by evaporation must be allowed for. The existence of these lakes points to two interesting facts in this connection : first, to the existence of pervious upper beds, and second, to impervious deeper layers which form an impounding reservoir for the water flowing from the supersaturated zone, where the upper pervious meets with the underlying impervious layer of clay. Now the maintenance of a more or less constant supply, in spite of evaporation, of the water in these shallow basins throughout the summer points to the existence of an extended water zone in the surrounding higher lands. Springs along the valleys do the same. At Aurora such supply the village with ample public water, while at Newmarket, as already mentioned, have been developed what seems on first appearances for this locality a remarkable phenomenon, namely, artesian wells. It is further interesting to note that for a considerable space at Holland Landing and to the eastward around the lake basin is a flat bottom land of fine sand. From this there is an abrupt ascent of clay, thence a depression till Newmarket is reached, some fifty feet above the level of the lake. Since I learned of the existence of artesian wells in Newmarket, I have been much disturbed as to how to account for them. They are, so far as I know, the only ones between the two lakes. Recalling, however, the existence of the sand flat surrounding Lake Simcoe at Holland Landing some fifteen feet above the lake, and finding from the levels that Newmarket is only fifty feet higher than Lake Simcoe at the railway station, I venture the following explanation as accounting, in part at any rate, for their existence. (See diagram, page 19.)

The fact of the existence of this sand layer and of the artesian wells makes us curious to learn whether, assuming it to be thus continuous, it appears to the south of the Oak Ridges. As Bond and other lakes lie about, on the height of land, only 26 feet lower than Oak Ridges and 200 feet above Lake Simcoe, it does not seem at all probable that the permeable beds which supply these lakes have anything in common with the aforesaid sand layer. The same level as Lake Simcoe 717 feet to the



Section of country between Lake Simcoe at nearest point, Holland Landing, and Lake Ontario. Heights above the level of Lake Ontario are shown, as als
the relative distances between places. Local variations in height are numerous.
Dotted area represents the sand stratum at Holland Landing continuous presumably with that under the superficial clay at Newmarket.

south of the watershed, arrived at along Yonge street, is seven miles south of Bond Lake ; and did these underlying strata maintain the same level, it would be near Thornhill that we would expect to find the layer of sand. If in this latter locality there should be found a widely distributed layer of water-bearing sand superimposed upon a bed of clay, and having a head of water extending back as far as the Oak Ridges, there seems no good reason why it should not supply ample water for the purposes of a large city. Remembering that McAlpine and Tully's scheme contemplated using the Bond lakes, Rouge, etc., and recollecting that their summer supply, constantly being reduced by evaporation, is wholly dependent upon these underground sources, apart from an occasional rain, there surely can be no reason why we should not find these same waters in greater quantities in the water-bearing sands and gravels from which they flow, and unpolluted by any surface wash or contamination or by the free vegetable growth which makes these lakes as they now exist such undesirable sources of supply. It will be seen how interesting this local supply becomes when we recognize that in the small area of a few miles we have, illustrated, the various sources of public water supplies. First, we have the various creeks of the water-shed, which uniting create on the east the branches of the Rouge and on the west the branches of the Humber, thus yielding a river supply undesirable because of uncertainty through evaporation during the summer and the certainty of surface pollution. Second, Bond Lake and her sister lakes forming reservoirs of water, made to some extent impure with surface drainage, but further enormously contaminated by deposits of organic matter which have been washed into them during the past and from the abundant vegetable growth always present in such shallow basins. Third, water from springs flowing from the hillside and supplying the village of Aurora with a public water of a perfect character as regards freedom from organic pollution. Fourth, at Newmarket, artesian water flowing clear and cold from a sand stratum over 100 feet beneath the surface. Now, in order to gather that portion of the waters from the first two classes produced from these underground supplies in the same state of purity as those in the last two classes, it is apparent that all that is necessary will be for a perforated tile of sufficient capacity to be laid at a gentle incline in galleries dug down to the hard-pan of clay along which the waters flow on the south side of the height of land and collecting them before they appear as springs at the surface, flowing thence into the lakes or creeks, at a time when they are in a state of absolute purity, due to their long underground filtration, and before they are contaminated by any surface wash. Examples of how this can be done may be seen well illustrated both in London and Brantford, where ample supplies of first-class water have been obtained ; but if we wish for higher authorities, because they are farther away, we may cite Toulouse, Florence, Lyons, etc., as examples of the method.

It now becomes of interest to enquire into the purity of these supplies. As you are very well aware we have distinctive classes of water, such as those of our great lakes, of our smaller inland lakes, of our rivers of the new districts, of rivers with towns situated on their banks, and of wells shallow, wells artesian, and deep pipe wells for pumping. These show that the various chemical compounds have certain general relations according as the waters have been churned up in the great lake reservoirs, have been flowing out of peat bogs, along clay banks or through limestone districts, whether they have received the surface drainage from cultivated land or from sewers, or from wells receiving a steady soakage from local sources of pollution, as soil contaminated with excreta or barnyard wash. All are aware that the rain water falling, chemically pure, at once dissolves from the surface soil whatever soluble materials are present, and that similarly as they descend into the soil they become loaded with organic impurities in the upper soils. In addition to chemical impurities, they likewise, through these impurities, become culture media through which infinite numbers of bacteria from the soil and air find abundant nutriment. Here again we find not only variations in the class of waters, which, according to their temperature, to the class of pollution and to their exposure to agitation and to the free oxygen of the air, present very different species of bacteria and enormously different numbers in a given volume. With regard to the bacterial life of waters under these numerous different conditions, we cannot be said as yet to have any complete or classified knowledge, but we do know that as the destruction of organic matter is slow or rapid, according to circumstances, so the degree of purity of a water for drinking purposes must depend upon the constancy of a settled condition unfavorable to a pollution from any source and remaining at a temperature inimical to the growth of bacterial life. Remembering it is only through the upper three feet of soil that organic materials with their contained bacterial life usually extend, and that it is therefore in these that the descending waters receive bacterial pollution, it is apparent that in the measure the waters continue to pass downward through permeable strata will they leave behind all suspended matters whether organic or bacterial, which they receive in the upper soils. Manifestly, however, the effect of the destructive influences going on in the soil will depend upon the depth of the organic materials and the porosity of the soil as regards movement of gases and the depth at which the bacteria of the soil are found to be capable of developing. Duclaux has stated that of the agencies which render water sterile in its passage through the soil, the first, the oldest known, and without doubt the most potent, is the capillary action of the soil. Filtration practically retains in the capillary pores the materials in suspension in the water, and with them the germs of microbes. It is a fact clearly demonstrated, he says, on which I shall only insist in order to attempt to indicate slightly what we call capillary filtration.

"It is proper to mention at the outset, that the capillary character of the channels in which circulates the water of rain has only the effect of augmenting the action of the surfaces on the volume of water which laves them, that is to say, of multiplying the chances which a solid particle in suspension in water can have of encountering a portion of wall on which it fixes itself, drawn by a force analogous to that which fixes coloring matter in a tissue placed in a coloring bath. The effect would be the same if the chances of contact were found increased by any other cause. . . . It could happen and sometimes does happen, moreover, that a long repose causes to adhere to the walls of a vase the particles held in suspension in the liquid which it contains. It can happen, and without doubt does happen, that a slow filtration through a great length of spaces non-capillary, and even somewhat large, produces the same result as through capillary spaces shorter and narrower."

Accepting these conditions as being those upon which the purification of ground waters depends, it is apparent that we have them supplied to the full in the case of those waters which create the enormous subterranean reservoirs which, we see, may result from downward movement of water through permeable soils. Further positive proof has recently been given us by the experiments of Carl Fraenkel, of Berlin, on the water of pit and driven wells, in which he shows that pit wells, owing to their receiving surface wash and soakage through their walls, as also owing to their communication with the outer air, are not only not sterile as are these deeper underground streams, but that, in the case of pit wells, in the neighborhood of habitations, these are too frequently found to be enormously contaminated. Thus in an unused well in the court of the Berlin Hygienic Institute, the water first removed was found to contain 10,800 bacteria in twenty drops.

To show the more or less constant differences in the chemical constitution of waters, I give here a number of analyses of Ontario waters from different sources:—

| Source of water. | In parts per million. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Chlorine. | Free ammonia. | Albumenoid ammonia. | Nitrates. | Oxygen absorbed in 15 min. | Absorbed in 4 hours. | Hardness before boiling. | Total solids. | Loss on ignition. |
| Lake Ontario at bell buoy | 3.0 | None. | 0.02 | 0.066 | 0.188 | 0.688 | 94.3 | 124 | |
| Lake Superior | 1.0 | 0.04 | 0.06 | | 0.27 | 0.35 | | 56 | |
| Lake Simcoe at Roach's Point | 0.5 | 0.04 | 0.12 | | 0.588 | 1.512 | 115 | 156 | |
| Bay of Quinte (Belleville) | Trace. | None. | 0.08 | | | 2.66 | | 142 | 60 |
| Bond Lake | 0.5 | 0.04 | 0.14 | 0.214 | 0.696 | 1.596 | 55 | 80 | |
| St. George's Lake | 0.5 | 0.32 | 0.20 | 0.049 | 1.220 | 2.828 | 142.1 | 192 | |
| Ottawa River | 5.7 | 0.07 | 0.014 | | 0.06 | | | 128 | |
| Niagara River | 2.0 | 0.04 | 0.12 | | 0.24 | 0.74 | | 133 | 48 |
| Kettle Creek (St. Thomas) | 2.0 | 0.20 | 0.08 | | 0.434 | 1.411 | | 240 | 84 |
| Artesian well (Leamington) | 1.0 | 0.10 | 0.04 | | 0.112 | 0.388 | 148 | 300 | |
| " " (Goderich) | 13.0 | 0.12 | Trace. | | 0.21 | 0.32 | | 540 | |
| " " (Barrie) | 7.0 | None. | None. | | 0.306 | 0.3568 | 175 | 284 | 112 |
| Penetanguishene (Springs) | 1.0 | 0.057 | 0.057 | | 0.30 | 0.085 | 235 | 205 | |
| Walkerton (Springs) | 1.0 | None. | 0.06 | 6.20 | None. | 0.108 | | 318 | |
| Orillia Asylum (Springs) | 2.0 | 0.04 | None. | None. | 0.346 | | 157 | 296 | |
| St. George's well near Bond Lake | 15.5 | None. | None. | | 0.148 | 0.400 | 278 | 464 | |

From studying these natural waters it becomes manifest that each has some certain characteristics attaching to it, possessing an advantage in some one or more particulars. Clearly, however, the more important question is that of their sanitary character; in other words, of (1) their freedom as regards bacterial life, (2) their freedom from such organic materials as form a pabulum for these bacteria, and (3) their freedom from exposure to those sources of animal contamination, whether direct or indirect, likely to introduce pathogenic forms of bacteria.

From the various classes of waters as we have seen them, and the characteristics which specially belong to each, it becomes easy for us to form conclusions as to what conditions become necessary to maintain such in a state of purity, or, when necessary, to subject them to such conditions as will alter them into waters of a superior class. To make plain what I mean, I would say that, on the one hand, we must seek to maintain underground waters, as those of springs and artesian wells, in a state of biological sterility. Hence, (1) we must not conduct them along natural channels or artificial ones made of soil of any kind; in other words, their conduits must be of masonry, tile pipe, or of iron, and (2) we must not, if possible, store them at all. But if this be unavoidable it must be as limited as possible, and in stand-pipes where a low temperature is maintained, and where the surface presented to the dust and outer air is as little as possible, or else store them in concrete-lined reservoirs, supplying those conditions found in a stand-pipe. On the other hand, if we are dealing with the waters of rivers and small lakes, it must be our aim to apply such methods as those which make sterile our standard underground waters. As seen these are, (1) a removal of the vegetable matter, both suspended and soluble, found in them. Hence we apply the principle of filtration on some such scale as we find going on in nature, and at the same time, by allowing the action of oxygen to go on in the reduction of soluble organic matters, as albumenoid decomposable materials, into fixed salts, such as those found sometimes in excess in artesian and spring waters. The same agencies must be set in operation even in a more thorough manner where, as in many river waters, the pollution is of animal origin, as sewage. Remembering, as Hofmann tells us, that the rate of movement of underground waters is usually not more than a few millimetres a day, it is hardly necessary for us to enquire whether a few feet of a bed of sand and gravel, of magnetic iron filings or of spongy iron, or of any of the much-lauded artificial filters now advertised for the market, can supply the conditions for removal of impurities by the law of capillarity and adhesion on the one hand, or of oxidation on the other, in any degree similar to those whereby underground waters arrive at that state of biological purity which is our ideal.

It was not without reason that legend and romance attached to the fountains of the sunny climes of classic lands specific virtues. Greece had her Castalian font on Parnassus consecrated to Apollo and the Muses; the Isle of Crete her "many fountained Ida," sacred to Jupiter; Petrarch celebrated the fountain of Vaucluse; while healing virtues have attached to many a St. Ninian's well and St. Margaret's spring. Certain it is that these ancients did not seek in their rivers for those waters of crystal purity which supplied for them the nearest approach to the nectar of their gods; but rather they found them in the springs of those sylvan abodes where, with so much reason, were located the habitations of their somewhat numerous divinities.

# THE SEPARATE SYSTEM AND THE BROCKVILLE SEWERS.

By Cesare J. Marani, Fellow in Engineering, S.P.S., Toronto.

*Mr. President and Gentlemen,*—In addressing the Engineering Society of the School of Practical Science, it would indicate a want of judgment on my part were I to dwell on the necessity of efficient sewerage, and upon the criminality—alas, too often entered into by civic authorities—of overlooking the means which science places at our disposal for decreasing mortality, preventing epidemics of the zymotic tribe, and preserving the health of our fellow-citizens.

In considering the sewage and sewerage questions, the only points where we may hold diversity of opinions are, the system to be adopted and the details of construction.

Before an examination was made into the several sewerage systems proposed for the town of Brockville, it was wisely considered advisable that such a plan should be adopted as would be capable of extension with the growth of the town ; so that the part first completed could, in the end, become a portion of an efficient and economical system for the whole town.

I need not give an account of the different systems proposed and upheld by different promoters ; suffice it to say that after a great deal of labor, thought, and time, had been expended by consulting experts ; after a certain survey and maps of the whole town had been made ; after levels and contours had been fixed, and the nature of the excavation on the different streets ascertained, it was decided to adopt the Modified Separate System.

With your permission I will say a few words in explanation of this system.

By the Separate System is meant a system which conveys house-sewage, and of course that water which comes from the flush-tanks, but excludes all rain water, both from the roofs and streets. It also excludes all cellar and soakage or underground water from its main artery. Cistern overflows, steam exhausts, and all that might be classed along with these, are of course excluded from the sewer.

Provision is made for the cellar and soakage waters by a line of ordinary porous agricultural drain tile laid in the same trench, but having no connection with the sewer proper. Advantage is taken of all such old sewers as are found in fairly good condition and which discharge readily into some water course or lake, as the case may be, to remove the storm water from the roofs and streets. Surface gutters are also used for this purpose.

From a careful digest of all that has been written for and against this system, I feel certain that those who have coursed their pens through the lengthiest manuscripts, or hurled their spears with deadliest aim at the Separate System, are just such as, only caring for fresh food to uphold their own conjectures, have not seen fit to discard self-inebriation for a moment in order to make themselves more fully acquainted with its *modus operandi.* From a theoretical as well as a sanitary standpoint, I consider that the Separate System is better adapted to the majority of cases than the Combined; from a monetary point of view it is far cheaper; and from a practical side, though it may sometimes be found advisable to allow certain portions of the system to be constructed on the Combined plan, yet it is just certain portions, and these are only on the branches and not on the main trunk of the sewer system.

Some forty years ago the excluding of the surface or storm water from the sewers was a departure advocated by several of the leading sanitary engineers in England, with this result, that several small towns were shortly afterwards sewered in that way.

In the year 1880 the attention of sanitarians and engineers in America was attracted by the sewering of Memphis, Tennessee, by Col. George E. Waring, in accordance with his extreme views. These views had been advocated by him a year before in a paper read before the American Public Health Association at Nashville, but the actual works brought the advantages of the system more prominently before the public. Since the year 1880 a great many of the American towns have been sewered according to this system, modified in the majority of cases, more or less of course, in order to meet the requirements of certain local peculiarities.

Permit me to read you some of the advantages of what is at present known as the Separate System from a paper read before the Brockville Sanitary Convention of last year by Mr. Willis Chipman, B.A.Sc., C.E.

(1) "The quantity of sewage to be dealt with is a comparatively fixed quantity, not varying from 1 to 60 as in the Combined System."

(2) "The quantity being small, sewers can generally be made of salt-glazed sewer pipes, impervious to liquids and gases, under ordinary working pressures, which offer a smoother surface than any brick or cement."

(3) "The sewers are regularly and thoroughly flushed by means of automatic flush tanks with pure water, while in the Combined System the rainfall is supposed to flush the system, but it is done irregularly and imperfectly."

(4) "The sewers have no connection with the cellars of buildings, the cellar and subsoil water being removed by separate conduits from the house sewage pipes."

The writer, after meeting the supposed disadvantages urged by the opponents of the system, goes on to say :

"This system is especially adapted to those towns in which the storm water can be removed by surface gutters or old drains with few long or expensive sub-surface channels."

"Secondly, those in which it is necessary to carry the sewage to any great distance."

"Thirdly, those in which it is now necessary, or will become necessary in the future, to treat the sewage, whether by sub-surface irrigation, broad irrigation, downward intermittent filtration, or by chemical precipitation and clarification."

In this paper it would be impossible to give as full a description of the Brockville sewers as they deserve ; I shall therefore try to point out only a few of the main characteristics in the work now almost completed.

Brockville is one of the first, I believe the only place at the present moment, in Canada where the Separate System has been carried out on a reasonably large scale.

The town lies on the north side of the River St. Lawrence, twelve miles above Prescott. It is mainly built on and around a slight hogsback or ridge which runs parallel to the river, and therefore increases the difficulty of sewering the back portion. The spur end of this ridge faces westward, the other end, gradually spreading out, is lost in the highlands further down the river to the east.

The town is therefore divided into two portions, one standing on the slope facing the river, and the other overlooking the country at the back. Around the foot of the spur we find Shepherd's Creek, to the west we find a colony of buildings which form the remainder of the town.

Through want of knowledge, stupidity, or faithlessness on the part of past civil officials, or what not, at all events a charter was granted to a company to build, manage, and control the Brockville water works ; and it was such that the company found itself at liberty to run its water mains in any and every conceivable direction, crossing and recrossing streets at any point wherever they might wish to do so.

As this charter contained no clauses properly restricting and regulating the laying of side branches and service pipes, these were therefore thrown underground in every imaginable shape. As an inducement to the company, and to help in defraying expenses, I suppose, that portion of Orchard street right at the water's edge was offered them free as a suitable site for their pumping-station. This being a central spot and giving scope for plans entailing the least expenditure in rock excavation, the company at once entered into a contract with the city fathers and proceeded to construct the works.

The result was that Brockville, after losing the smooth road surfaces, suffering from badly filled trenches, blocking of streets, delays in carrying out the works, and a score of other nuisances that spring out of poor workmanship and worse management, at last possessed the desired waterworks, which, owing to the terrible want of system both in their plan and execution, proved an energetic factor in raising the cost of construction of the sewers that were to follow.

This town, being one of the oldest in the Dominion, suffers from the fact that no matter in what direction you may run a trench on any street (except on those which have rock close to the surface), you cannot proceed many paces before you strike a regular nest of box drains, of all sizes and ages, running at all angles and elevations below the surface, and in all directions conceivable.

Some will be found comparatively new and in use, while others will be old and rotting, not having been used for years, but in most cases full of soakage water. This water bursting out into the trench gives endless trouble. Some of these drains are public, but others again are private, the owners holding special permits and rights which protect their position, and renders their removal, even by the engineer, very troublesome.

Owing to the amount of rock in Brockville, gas pipes were also laid crossing and recrossing the same street from side to side so as to avoid blasting as far as possible. From these among the many local difficulties that presented themselves, we can easily see that to attempt the introduction of a sewerage system in the town of Brockville, comprising both economy and efficiency, was no easy matter.

One of the greatest difficulties arose from the position of the waterworks pumping-house and intake pipe. A trunk sewer, running along Water street, capable of carrying twice the sewage of the whole town, and ending in a costly cast-iron outlet-pipe emptying below the said waterworks and in mid-current, suggested itself as the only remedy. But then, again, how could this trunk sewer be passed under the railway tunnel at the foot of Market Square, so as to catch all the sewage from the back part of the town?

This should bring vividly to view the necessity for careful thought and sound judgment on the part of an engineer before ever a spade is turned or a scratch of the pen made.

The system of sewers adopted in the town of Brockville is the Modified Separate System and is designed to carry off :—

(1) Liquid house wastes.
(2) Excreta.
(3) A limited amount of roof water.
(4) Subsoil and cellar water by special conduits.

The main sewer and laterals consist of vitrified salt-glazed sewer-pipe of Scotch, St. John's, and Hamilton make, and called sewers, designed to carry off the liquid house wastes, excreta, and the above limited amount of roof water.

Alongside of the sewers are laid agricultural drain tiles, one foot to a foot and a half in length, and three to six inches in diameter, and designed to carry off the subsoil and cellar water.

At the top of each of the branch lines leading from the main trunk sewer, we find an automatic flush tank, arranged to discharge 200 gallons of water twice a day.

When this water is discharged into the sewer it flushes all parts, and especially those of least grade, which require it most.

Nearly all those branch lines are nine inches in diameter, but vary from 900 to 3,300 feet in length; the flattest grade being about 0.32 feet per hundred, and the steepest probably 8.00 feet per hundred. All points are gasketed and cemented in the most approved manner, the cement used being the very best Portland, having withstood a tensile stress of over 120 lbs. per square inch after one hour's exposure in the air, and 24 hours submersion in water. It is used mixed with an equal portion of clean sharp sand.

Manholes or sampholes are met with at the intersection of every street, the sewer running straight and at a uniform grade between manholes or between a manhole and samphole or flush tank, as the case may be.

By this method the sewers can be readily inspected and cleaned if necessary. All junctions of mains and laterals are made inside of manholes, a Y or T junction, according to the depth of the trench, being placed opposite each house or vacant lot, and at such a point as to render it of most service.

From each cellar comes a line of from three to four-inch agricultural drain tile, which in the majority of cases runs up to, but does not break into, the trench line running along the side of the salt-glazed sewer, and therefore reducing in a great measure the possibility of vermin emigration.

The main trunk, which collects nearly all the sewage of the town, starts as a 12-inch sewer, swells to a 15-inch before it reaches Mill street, and then to an 18-inch, when it has only .16 of a foot fall per hundred. On Water street it passes as an 18-inch cast-iron water-pipe right under the C. P. R. tunnel without an invert or bend of any kind; beyond it continues as a soft-glazed pipe at the bottom of a trench, in many places nearly 13 feet deep, and at last it reaches the lowest manhole in the system, at the foot of Ford street, where the submerged outlet pipe begins.

This outlet consists of 16-inch cast-iron water piping over 900 feet in length, and running diagonally across and down the river.

The outfall is located in 45 feet of water and right in the current; contamination of the water supply is therefore rendered impossible.

Wherever practicable, the sewers have been laid in the centre of the streets.

On account of the Shepherd's creek to the west, the cluster of buildings beyond had to be drained by a small and separate system from that of the town. Their sewage empties into the river at a point above the water-works intake-pipe it is true, but the distance is great compared with the amount of sewage discharged, and experiments with floats have shown that the current at this point is up stream, this being caused no doubt by the position of the islands and also by the length of the C. P. R. wharf a little lower down.

Plans and records have been kept of the depth and grade of every sewer, the location of all flush tanks, sampholes, manholes, etc., also the position of all gas and water-mains, including all those service pipes, both for gas and water, that were met with in the trenches.

The average cost for five of the 9-inch sewers built on the frontage or local improvement plan, namely, Orchard, Market, Bethune and branches, Ormond and branches, and Pine, has been about $1.55 per lineal foot.

The average cost of the main sewer east of the tunnel has been about $3.88, while the portion to the west only cost $2.80 per lineal foot.

When we consider the uneven character of the soil, those local difficulties peculiar to Brockville alone, the hardness and quantity of the rock to be excavated, the difficulty of securing sufficient material, when most needed, to keep the works going, the fact that the character of the work and its dimensions here in Canada were new, and that therefore manufacturers of porous tile, salt-glazed pipe, bricks, etc., were at first unprepared to provide goods of the standard required and in the quantities called for, we wonder that so effectual a system could have been completed at these figures. It certainly reflects great credit on the chief engineer, Willis Chipman, B.A.Sc., and leads us to suppose, and in fact feel certain, that the majority of our Canadian towns could enjoy a similar system considerably cheaper.

# NOTES ON RAILWAY LOCATION AND CONSTRUCTION IN THE NORTH-WEST.

By T. S. Russell.

There are several points in which the construction of railways in Manitoba and the North-West Territories differs from eastern practices. The most noticeable, perhaps, is the quickness with which the surveys and construction is carried on.

It is my intention in this paper to give a few notes on general western work, which I shall put in the form of a short history of the building of an ideal railway. I will at the outset remind those who may be disposed to criticize the manner in which these roads are built that, while eastern railways are generally built to connect towns and cities, between which they have an assured traffic, and have therefore some good prospect of paying expenses at the start, western roads are, as a rule, projected through an unsettled or sparsely settled country, which has first to be peopled by immigration before the required traffic returns can be hoped for. Add to this the fact that, with the exception of earth, all materials of construction are much more expensive than in the east, and it is not surprising that western railway companies try to build their roads as cheaply as possible.

In the month of May, 1888, two young engineers, one of whom I shall call Patterson, the other, the writer of this paper, were kicking their heels in Winnipeg, impatiently waiting for the opening of work on the railroads, ready to take almost any position which might be offered on an engineering party. When a whisper reached their ears that Mr. Smith, the chief engineer of the Sod Town Railway, was in the city, and about to organize a surveying party to locate the line of said railway, they immediately hunted up the gentleman and learned from him that for once rumor spoke truly; and as they were fortunate enough to be the first applicants they were offered work, Mr. Patterson as transit man, the writer as leveller, positions which they both accepted without delay. They were ordered to engage their own picket men and rod men and report on the following day, and to hold themselves in readiness to go west at a day's notice.

Within three days this notice came. Everything had been collected and put on the train—tents, cook's outfit, instruments and party, and after a few hours run on the C.P.R. the first representatives of the Sod Town Railway were deposited at Sod Town Station. The first proceeding was to overhaul the camping outfit and put up the tents, which were five in number. First and foremost, according to the unwritten law which governs all surveys, the cook's tent, which served also as a dining tent, was erected ; then came the chief's tent, which was shared by the engineer in charge, the transit man, and the leveller. The office tent came next, and then two more, in which the other members of the party slept.

Having superintended the erection of the camp, Mr. Smith went off to the town to make arrangements for a permanent office there. . The transit man and the leveller started off on an exploring expedition, mounted on two gay and festive bronchos from the nearest livery stable, and hunted up a few section lines and explored the first three or four miles of country through which the new railway was to pass. At six o'clock the party reassembled in camp around the dinner table to test the merits of the cook, whose office is by no means the least important on a survey, and to make each other's acquaintance.

Besides Mr. Smith and the two instrument men already referred to, the party consisted of one rod man, two picket men, two chain men and one man to carry and drive in stakes, two teamsters, and the cook. Axe men were not necessary, as the prairie was quite destitute of any vegetation longer than sage bush, except near the banks of streams and rivers, where a few scattered poplars were found. As night came on the various members of the party betook themselves to their tents ; the chief, with the transit man and the leveller, held a consultation in the office tent, and laid down on the map a line to be run on the following day. This done, they went to their sleeping tent and turned in, but it was not an easy thing to go to sleep on the first night in camp, so that the first hour or two was spent in relating experiences on former surveys, and in listening to the choruses which came from the other tents.

Next morning's train from the east brought two more officials of the new railway, Mr. Hustler, who was to take charge of the location, and Mr. Quill, a draughtsman, who was to remain in Sod Town in charge of the office. The chief engineer had decided to remain in the town also, or at least to make this place his headquarters.

The regular work of the party began by running in a curve from the main line of the C.P.R., and then off on a long tangent. First went the front picket man with the two chain men and a man to carry stakes These were marked in the usual manner and lined in by the transit man. Hubs were put in about a half mile apart, and the line was projected by means of back pickets, a man being left behind to hold a picket on each hub over which the transit was last set up. The leveller and a rod man always kept behind the transit man.

The height above sea level was obtained from the C.P.R. and a bench mark established near the beginning of the survey. As there were no trees or stones on which to establish bench marks along the line, a bench was taken on each hub left by the transit man, the elevation being marked on the hub stake and entered in the level book. As the country was fairly level and without obstruction, the work went ahead very quickly.

On our first day we ran a mile and a half of line, on the second four miles, on the third five miles, and at the end of two weeks we were able to average seven or eight miles per day, except when we had to back up to try new lines, or change our course and run on curves. We moved camp about twice in three days. The cook and one teamster with an extra man attended to this work, the other teamster drove the party to and from work, carrying stakes, lunch, and such things as the party required during the day. Mr. Hustler, armed with a pocket-compass, hand-level, and map of the country, went ahead, either on horseback or driving in a buckboard.

The manner in which the land in the North-West is surveyed makes the running of railway locations and trail lines an easier matter than in the east; but as this system of survey has been so often referred to I shall not describe it here. In railway surveys the problem usually is to get the shortest possible route between a certain number of fixed points. When two of these points are known with reference to the system of land survey, the calculation of the course of the straight line connecting them and its length is a very simple matter.

The intersection of each land line with the line of railway should be taken by the transit man, and the distance to the nearest post measured and recorded in the transit book. In the evening he should plot this line, showing intersections with all land lines and the topographical features of the country on each side of it. The leveller should also plot his day's levels on profile paper every evening, and try grade lines, so as to form some idea of the probable cost of earth work. He must also note in his level book, and on his profile, all places where culverts and bridges will be necessary, although the fixing of grades and distribution of culverts is finally attended to by the engineer in charge.

The country through which the first sixty miles of our Sod Town Railway ran was fairly well settled for Manitoba. At first nearly every section had one, two, or sometimes four houses on it. As we moved farther away from the C.P.R. the number of settlements grew less; still for the first sixty miles we were never out of sight of houses. Sometimes, early in the morning, we could see houses all around us—hundreds of them apparently—looking, in the distance, like towns and villages. On account of a mirage which often occurs on the prairie, buildings twelve or fifteen miles away could be seen very clearly, and appeared to be only a mile or two distant, but as soon as the sun rose this illusion vanished. Perhaps such scenes are, as one of our party remarked, prophetic visions of what will be seen in reality in the course of a few years, when the country is better opened up and more thickly settled.

We ran through numerous grain fields, past cattle and horse ranches. One evening we met half a dozen travellers, who had camped for the night on the trail; their horses were turned loose to graze. One of the party was cooking supper at an open fire, another was making beds under the wagons, for they seemed to think a tent was an unnecessary luxury. They were farmers, they told us, and were bringing in their wheat to the nearest mill on the C. P. R. They had already come fifty miles, and had forty more to go before reaching their destination—Sod Town. Ninety miles to haul wheat and farm produce to the nearest market, and ninety more to return to their farms! Truly, railways are badly needed in the North-West.

Our survey line crossed two or three streams and small rivers, but we had no difficulty in finding good crossings. The largest, which rejoices in the name of Whiskey creek, gave us a little trouble. It runs through a valley about a mile wide and 150 feet below prairie level. One aggravating feature about this river, a feature that was noticed in the case of many streams, was that the prairie rose, approaching the river, until the edge of the valley was reached, and then dropped down 150 feet at a jump, as if the valley had been scooped out and the excavated material spread on each side to make it as difficult as possible to get a line down into the valley with easy grades. But by running along the side of the valley for about three miles, we managed to get down with a maximum grade of .7 feet per 100. Our maximum grade leaving the valley was one foot in 100. Since on this railway the bulk of the traffic is expected to be easterly, we tried to keep our grades going east below .7 feet per 100 as a maximum.

This location was, from its nature, very slow and hard work, and we camped in this valley for a month before we succeeded in finally locating six miles of road. The creek itself was a very insignificant affair to be the proprietor of such a large valley. It was barely 200 feet wide, and nearly dry where our line crossed it.

We now struck straight west, and soon left the boundary of Manitoba behind us. We left all traces of civilization behind us also; very seldom did we see any person outside our own party. Occasionally a few Indians would honor us with a visit, or a red-coated mounted policeman would call at our camp if it happened to be on the route of his patrol.

When we had run about 200 miles of line we were recalled to Sod Town. The company, it seems, had decided to build about sixty miles during the present season, and we were wanted to look after the construction. We therefore turned our faces eastward, and in ten days reached the point from which we had started our line some two months before.

During the progress of our survey we had from time to time sent in to Mr. Smith, at Sod Town, copies of our transit and level notes. We now found that Mr. Quill had been at work on these notes, and had prepared plans and profiles from them. All the plans of locations, structures, and profiles, showing grades, had been prepared for the first sixty miles which the company intended building. A right-of-way agent had been engaged to purchase the necessary land for right of way. The contracts for the earth work had been signed and the contractors were already on the ground prepared to go to work. There were two firms of contractors between whom the work was divided, thirty miles to each firm. Mr. Smith decided to divide the engineering and supervision of work in the same way, placing Mr. Patterson in charge of the first thirty miles, and myself in charge of the second thirty, as assistant engineers. We both were ordered to report to Mr. Hustler, who was the division engineer, and who took charge of all matters connected with the construction.

As the contractors concentrated their forces as much as possible, the work of looking after thirty miles was not so difficult as might at first appear. The contractors began at the beginning of their contracts and worked straight ahead, finishing up as they went along, and thus they did not as a rule work on more than five miles at once.

Before leaving Sod Town to take charge of our sections, Mr. Quill furnished us with working profiles, showing the grades adopted, the various culverts, bridges and crossings to be put in along the line, and with stationery sufficient for our field offices. We each took three tents, one to be used as an office tent. We also took with us a horse and buckboard, a rod man, a tape man, and an axe man. We took no cooks, but made arrangements for boarding either with the contractors or with farmers.

On reaching my section I began at once to cross-section and lay out the work in the usual manner practised, so far as I know, on all railroads. As most of you are probably familiar with this operation, and as it has several times been described in papers read before the Society, I shall not refer to it except to say that while on eastern roads the engineer pays particular attention to the cross-sectioning of cuttings, and is less particular in cross-sectioning fills, the reverse of this rule is observed on prairie roads. The reason for this is that in the east it is customary to measure and pay for the earth actually excavated in the cuttings and ditches, or borrow pits, and to pay no attention to the theoretical bank quantities, except, perhaps, as a check. While this method is undoubtedly the most accurate, as the shrinkage of the earth in embankments makes the theoretical bank quantities less than the true quantity excavated, yet on prairie roads, where the work is done very rapidly and cuttings are avoided as much as possible, the measurement of ditches would entail a vast amount of work in a very short time, and necessitate the employment of a great many engineers. Then, as these ditches are often irregular in cross-section, it would be a difficult matter to measure them accurately, besides the prices paid for earth on the prairie are so much lower than in the east, and the quantities per mile, as a rule, so much lighter, that the difference in the amounts which would be paid to the contractor by the two systems of measurement is not very great.

I found it a good plan in cross-sectioning to run straight ahead as in ordinary levelling, taking sights along the centre line and to the right and left when necessary, without marking any stakes or putting out any slope-stakes, except where there was a change from a fill to a cut, or *vice versa*, in which places I put in the necessary grade hubs and grade stakes, marking the exact points at which these changes took place before proceeding further. After having run on in this manner until about three or four o'clock in the afternoon, I would then put my level away and drive slowly back along the line. I would hold the reins in one hand and my cross-section book in the other and call out the cut or fill at each station, and the distances out for the slope-stakes; the men who walked along the line would mark the proper cut or fill on each centre-stake and put in the slope-stakes.

A supply of stakes was always kept on the back of the buckboard. By working in this way I could save a good deal of time, and could on fairly level ground lay out three or four miles per day.

In cross-sectioning we laid out the dump fourteen feet wide, and the cuttings twenty-two feet wide. In cuttings of less than four feet we made the side slopes two to one, three to one, or four to one, according to our judgment in each case, the idea being to make a gentle slope and thus lessen to some extent the danger of snow blockades in winter.

As soon as the ground was cross-sectioned, the contractors went over it and drove down at each centre-stake a stout poplar stake, making its height above ground correspond to the fill marked on the centre-stake. They also drove down shorter poplar stakes to mark where the slopes of the dump would come, as our slope-stakes were usually very light and perishable affairs. They then brought on their graders and scrapers, and the various apparatus used by them for the purpose, and proceeded to throw up the dump and haul out the cuttings as quickly as possible.

The New Era graders were used by the contractors of whose work I was in charge. I shall not attempt a very lengthy description of them, as they are fearfully and wonderfully made. The remark which is reported to have been made by a farmer of the old school on seeing a self-binder for the first time would apply to these "infernal machines," as some engineers call them, that "It would be no sin to fall down and worship them, as they resemble nothing in the heavens above, or the earth beneath, or the waters under the earth." The principal parts of a grader are a plow which can be raised or lowered by means of chains running over pulleys, and an elevator, which is simply a rubber belt about thirty inches wide working over two revolving pulleys. The plow turns up the sod and throws it on the belt of the elevator, which revolves so as to carry the sod up along an inclined plane and drop it at a distance of sixteen or eighteen feet from the ditch. The grader is drawn by six teams, four in front and two behind. Three men can work it, one to drive the front teams, one to drive the two rear teams, and the other to raise or lower the plow. The raising or lowering of the plow regulates the amount of earth moved. Four feet is the greatest height of dump that can be built with this machine, but it is used by many contractors for the bottom of all fills, the fill, when it exceeds four feet in height, being finished with scrapers. Under favorable circumstances, a grader will throw up about 1,000 cubic yards per day.

These grading machines make a very pretty ditch but a very loose and unsatisfactory dump. The sods and earth are dropped from the end of the elevator, and as no weight or pressure is applied to solidify them, the dump built with the grader only is very soft, often so soft that a man walking on it will sink six inches in the earth, and it keeps settling as time goes on under the influence of rain.

To remedy this evil some railway companies make the contractor put up all dumps, finished with the grader only, two-tenths of a foot extra for every foot the dump is in height; thus they would have to make a dump intended to be three feet high 3.6 feet high. Other companies do not allow any work to be finished with the grader, but oblige the contractors to put on the last twelve inches on dumps with horses and scrapers. The tramping of the horses thus solidifies the whole. I have yet to meet the first engineer who has a good word to say for these grading machines—that is, for the ordinary purposes of railroad building. Their work is very unsatisfactory, and as a consequence they are a source of frequent disputes between the contractors and the engineer. When the contractor is bound by agreement to use his graders only for the foundations of dumps he has to be watched constantly or he will exceed his limit, for work can be done much cheaper by the grader than in any other way. The use of grading machines has reduced the price paid for earth in Manitoba as low as seven cents per yard.

On the profile given to me by Mr. Quill, the location and size of each proposed culvert and trestle was marked. The contract for earth work did not include bridging, so I was only concerned about the size of the opening to be left, and about leaving such openings in the best places. In this work I had to follow my own judgment to a large extent, changing either the size or location of structures when there appeared to be a necessity for it. The chief engineer often locates these structures from an inspection of the profile and a single drive over the line, and it is only natural, therefore, that the assistant engineer, who goes over the section every day or two, should be able to suggest improvements, which he is usually allowed to make, first obtaining, in important cases, the advice and consent of the division engineer. To the assistant is left also the location of farm and road crossings. Road crossings are of course put in where the railway line crosses the regular road allowance; farm crossings, at such places as may be agreed upon by the assistant engineer and the owner of the land, one crossing being allowed for each quarter section of land. When these points are finally settled, a list is made out of all crossings, culverts, cattle-guards, and structures of all kinds, with the numbers of the stations where they are to be put in, and copies of this list are sent to the contractor and to the chief engineer. The location of these structures is also indicated by stakes, which should be put in at the time of cross-sectioning, or as soon as possible after. The contractors are required to excavate a foundation for box culverts below prairie level, such work being paid for at the usual rate.

During the progress of construction, we were kept busy giving the contractors grades in cuttings, and on high dumps, when they were not able to put in stakes high enough to reach to the top of the dump. When any part of the work was finished, I ran centres and grades over it, to determine whether or not it was properly built on the original centres and up to the required grade. If found wanting in any respect, the contractors were notified to go over it and make it right. They generally did this very reluctantly and with a great deal of grumbling in some cases, but a few occurrences like this made them more careful in future.

At the end of each month an estimate of the amount of earth handled during the month had to be sent in to the head office, and on the completion of the work a final estimate of the total quantity of earth handled, including all crossings, and in some cases culvert excavation and ditches, the material from which was wasted by orders. The prices paid for earth were eight cents per cubic yard for all earth hauled less than 200 feet, and twelve cents for all hauled more than 200 feet and less than 600 feet, and for earth hauled over 600 feet one cent per additional 100 feet of haul. It was necessary, therefore, to state in the estimate how far each quantity of earth had been hauled. Earth was not hauled more than 200 feet, except in the case of cuttings, where the earth had to be hauled each way from the centre of the cutting to the adjacent fills, and in the case of very heavy fills where sufficient earth could not be obtained within 200 feet of the dump. In the former case I calculated the amount of the over-haul by plotting the quantities in the cutting and the adjacent fills to a scale; the horizontal distances were indicated by the numbers of the stations, representing distances, along the line; the vertical ordinates represented cubic yards. The number of cubic yards plotted opposite each station is the total number from the beginning of the cut up to that point, and these points are joined so as to make a curve of quantities. This curve of quantities is drawn for the cut in two parts, one commencing at zero, at the beginning of the cut, the other commencing at zero, at the end of the cut, the curves intersecting near the middle or at the exact centre of gravity. A similar curve of quantities is plotted for the fills adjacent to the cut. By finding with a scale or pair of dividers the two points, one on the curve of the cut, the other on the curve of the fill, which are 200 feet apart on a horizontal line, we obtain from the ordinate of these points the total quantity in that end of the cut hauled less than 200 feet. By the same method we find the points on these curves between which the horizontal distance is 600 feet. The ordinate of these points give us the quantity hauled from 0 up to 600 feet; subtracting our first ordinate from the second gives us the quantity hauled more than 200 feet and less than 600 feet, or our over-haul for which twelve cents per yard was to be paid. Similarly, we can find the amount of the over-haul for each additional 100 feet. When the length of haul reached 1000 feet our instructions were to allow the contractor to waste the earth in the cutting, as it was cheaper to pay them eight cents per yard for wasting, and eight cents more for borrowing earth for the fill, than to pay over sixteen cents for over-haul.

The calculation of the quantities for the estimate gave us a lot of work. Mr. Patterson and I calculated our quantities on sheets of foolscap during the evenings and on wet days, and then exchanged level books and estimate sheets, so that each checked the other's work.

It is wise to do this work early in the month, and not leave it all to the last moment and then have to work night and day to get the estimates off in time. I used two methods for calculating these quantities; the first was for cases where the ground was level, or nearly so, and the readings at the slope-stakes the same as at the centre, in which case I used Trout wine's tables of quantities for a fourteen-foot bank, and calculated from them. The second method was for cases where the ground was sloping and it was necessary to consider the heights at the slope-stakes, or other points in the cross-section, in which case I calculated the area of each cross-section in feet, averaging the areas and multiplying by the distance between them, then converting the result into cubic yards. The first is a method of averaging heights, the second of averaging areas. These calculations were, of course, made from the figures in the cross-section book. The quantities in the cuttings were calculated by a method similar to the second here given.

An objection may be urged against these methods, in that they are not mathematically correct, but in no case can one be sure of mathematical accuracy when calculating earth work quantities. The first method, in which the centre heights are averaged, makes the quantity too small; the second, in which the areas are averaged, makes the quantity too large. The prismoidal formula would come nearer the truth, but life is too short and time too precious to admit of its being used. Some engineers are fortunate enough to possess tables calculated by the prismoidal formula, and extended so as to give the cubic contents of prismoids with very large and very small end areas, and these are very useful and accurate.

The following figures will give an idea of the cost of earth work per mile on prairie railroads. Quantities of earth on 16.68 miles of railroad —rolling prairie :—

| | | |
|---|---|---|
| 139,067 | cubic yards hauled 200 feet, @ 8 cents | $11,125 36 |
| 10,781 | " " " 200 to 600 feet, @ 12 cents | 1,293 72 |
| 7,147 | " " " over 600 feet, @ 26 cents | 1,858 22 |
| | Total | $14,277 30 |
| | Average cost per mile | $855 95 |

This is for earth work *only*. Another average of the cost of earth work on twenty-three miles of road makes the cost, at the same prices above quoted, $667.89. In this case the prairie was more level.

After the completion of the earth work the bridging engaged our attention. In this paper it will be possible only to outline the work done on bridges. With the exception of our wooden truss bridge over Whiskey creek, the structures were of four kinds: 1. Timber box-culverts; 2. Timber open culverts of fifteen feet span; 3. Pile trestles; 4. Framed trestles.

All structures were of wood. The box culverts were very simple affairs, built of cedar, the average opening being two and a half feet vertical by three feet horizontal.

The fifteen feet open culverts were used in places where the bank was less than five feet high. They consisted of two bents of six piles each, backed by a wall of 10″ x 10″ cedar, which acted as a retaining wall to keep the earth of the dump from falling into the opening. The piles in each bent were driven as follows: Two inside piles five feet apart, or 2′ 6″ from the centre of the track; then two eleven feet apart, each 5′ 6″ from the centre of the track; then two outside piles were driven one-third of the way down the slope of the bank to assist in supporting the timber wall. On top of the four centre piles a cap 4′ x 12″ x 12″ was placed, and on this the stringers were fastened; finally, on the stringers the ties and guard rails were arranged in the usual manner.

The ties, stringers and cap were fastened with ¾″ drift bolts, and the guard rail 8″ by 8″ was let down on the ties 2″. The guard rails and ties were then bolted together through every fourth tie by ¾″ bolts. In all cases the span for these culverts was fifteen feet.

The pile trestles were built with bents, fifteen feet apart, four piles in each bent, the two inside ones being five feet apart, one under each rail; the two outside ones were eleven feet apart.

The piles were braced diagonally by bolting to them 3″ plank. The arrangement of the caps, stringers, ties and guard rails was the same as for the fifteen feet open culverts, except that three stringers 5″ x 14″ and 7″ x 14″ were used in alternate spans under each rail. The spans built in this way were forty-five feet, sixty feet, seventy-five feet, and so on, the distance bridged being always a multiple of fifteen feet.

In these trestles no retaining walls were put in, the earth being allowed to slope under the trestle. All trestles over twelve feet in height were framed. These frames consisted of a 12″ x 12″ sill and cap, the latter fourteen feet long, two vertical 12″ x 12″ posts five feet apart, and two bottom posts 2″ x 12″, eleven feet apart at their tops, built with a bottom of one-quarter horizontal to one vertical. These frames were braced diagonally, and also fastened to each other horizontally. They rested on piles which were cut off close to the ground. The arrangement of stringers, ties and guard rails was similar to that already described.

The work on these bridges was done by a different firm of contractors from those who did the earth work. In order to save expense in hauling timber, they waited until the track-laying started before beginning work on the bridges and then finished them up just ahead of the track.

Mr. Patterson, who took charge of the bridging, laid out the culverts and trestles, putting in stakes for each pile separately and giving heights with the level for cutting off the piles. He had also to inspect all the timber used in construction and see that no bad material was used, and that the structures were built in accordance with the general plans sent to him by Mr. Smith.

I took charge of the track-laying, but as this part of the work was referred to in a former paper I shall say nothing about it here. After the track-laying came the erection of tanks and buildings. Mr. Hustler took charge of this branch of the work, and Mr. Patterson and I, finding that the Sod Town Railway Company did not require our valuable services any longer, decided to come down and visit our friends in the east.

# FOUNDATIONS.

By R. McDowall, Grad. S. P. S.

One of the commonest expressions in literature in regard to man is, "Build on a sure foundation." And to insure a structure against destruction, one of the chief requisites *is* a "sure" foundation.

The subject of this short treatise is to give a general description of how foundations are obtained.

Foundations must not be considered bad even if they do settle below their original level, but the whole surface must sink uniformly without any tilt.

We will divide our subject as follows :—

(1) Rock foundation,
(2) Dry soil foundation.
(3) Under water foundation.
(4) The coffer-dam.
(5) The caisson.
(6) Interesting details.

(1) *Rock.* Of course rock forms the best foundation, but in some instances it is unreliable. If it be shaky or shallow in depth, all shakes must be removed, and all hollows, cracks, etc., must be filled with concrete. If the bed of rock has a dip, it will have to be "stepped" in order to prevent sliding. To test the nature and depth of the strata, several holes should be drilled from three to four feet deep. Rock must be removed generally by blasting.

(2) *Dry Soils.* In good dry soils the foundation must be sunk to such a depth as to be entirely out of reach of atmospheric influences; also the depth should be proportionate to the weight of structure to be built upon it, or the soil will squeeze up about the structure and the foundation will settle. In compact gravel the pressure per square foot of foundation surface should not exceed two or three tons, and in clay, one or two tons. All kinds of tremors help settlement. Equality of pressure is a great point to be gained.

(3) *Foundations under Water.* The great difficulty in placing foundations under water is that of getting rid of the water while excavation and building is being done below water-line. The same kind of soils is found below as above water, but wet soils stand a less pressure than dry. But in water, foundations have to be sunk a great deal deeper than on dry land,

in order to prevent "scouring" or washing out of the soil from beneath the structure, especially in a rapid current. In shallow water, from two to three feet, a bank of clay around excavation is sufficient to keep out the water. In greater depths, as from three to twenty feet, coffer-dams will be required. A coffer-dam consists of two rows of sheet-piling driven about a rectangular space, in which space the excavation is to be commenced. In the space, which is about five feet, between the two rows of piles puddle is placed in order to make it water-tight. Puddle is the name given to whatever material is used, sometimes gravel, sometimes clay, and sometimes a mixture of each with pea straw. Blue clay, from my experience, makes the best puddle. Of course the material close at hand should be used, as it would be very expensive to haul any specified puddle from a distance. The slime on the river bottom should be removed from between the rows of piles before the puddle is placed, so as to allow it to combine with the hard soil at the bottom of the water-basin. If there is a leak in a coffer-dam it generally is at the line where the puddle meets the bed of the river, etc. This slime can be removed from under water by use of a clam dredge. The timber used for sheet-piling is cedar, from twenty-four feet to thirty-six feet long, eight inches thick, and of various widths. It is tongued and grooved in order to more effectually keep out silt. A walling of hardwood (elm is good) surrounds each row of piles, and is bolted to them. The two rows of piles are also connected by iron rods at their top to prevent spreading.

The water inside the coffer-dam is pumped out, and if any leaks should appear they are at once stopped. The centrifugal pump is the best kind for pumping muddy, silty water; one having a 6-inch discharge pipe will throw from 300 to 400 gallons per hour. In any ordinary coffer-dam a single pump should be sufficient to keep it dry and not be working half the time.

The material inside of the coffer-dam is generally excavated by hand, placed in buckets and hoisted by a steam derrick. These buckets dump themselves by being tripped by a line. If at required depth a good bed of gravel or rock is met with, the surface is levelled and the masonry is commenced. But should the bottom be of a soft nature, as quicksand, etc., piles will have to be driven.

Bearing piles are generally from twenty-five to thirty-six feet in length, and from eight to twenty inches in diameter. All kinds of woods are used, but the best are cedar and spruce. They are driven in rows in the foundation spaced about three or four feet apart. The piles are driven by a pile-driver. It consists of two well-braced "leads" made of timber and spaced sixteen inches apart. Between these leads a hammer works freely up and down. The hammer is drawn up by a rope attached to it and passing over a pulley at the top, thence to a pulley at the bottom, and from there to the drum of a hoisting engine. In hoisting with a steam engine the rope is continuously attached to both hammer and drum, and in this way an engineer can strike his pile light or heavy blows by the use of his friction lever. A pile inspector can be thus led astray when he sees a pile stand a full drop blow without budging, while all the time the engineer is striking light blows. Iron rings should be placed about the heads of the piles to prevent them from splitting.

The formula for finding the bearing load of piles is the following:—

$$L = \frac{H^{\frac{1}{3}} \times .023W}{S \times 1} \begin{cases} L = \text{load in tons.} \\ H = \text{fall in weight.} \\ W = \text{weight of hammer in pounds.} \\ S = \text{last sinking in inches.} \end{cases}$$

*Example.*—Suppose a pile fourteen inches in diameter and thirty feet long is struck by a hammer weighing 2,000 lbs., and falling twenty-seven feet; find its sustaining power and the friction per square inch on its sides, the last sinking being two inches:—

$$L = \frac{27^{\frac{1}{3}} \times .023 \times 2000}{2 + 1} = 46 \text{ tons} = 92000 \text{ lbs.}$$

$$\text{Area in sq. inches} = 14 \times \tfrac{22}{7} \times 30 \times 12 = 15840 \text{ sq. inches.}$$

$$92000 \div 15840 = 6 \text{ lbs. per sq. inch.}$$

The driving of a number of piles in a foundation throws up a considerable quantity of material. All the piles are now cut off at the same level, and the earth is excavated from about them to the depth of two or three feet. Timber caps twelve by twelve inches are bolted to the top of the piles. Rag-bolts twenty-four inches long and three-quarters of an inch square are used. Then the whole of the spaces between piles and caps is filled in with concrete well tamped down. Upon these caps a longitudinal flooring of twelve by twelve inch timber is bolted. This flooring should be laid so as to break joint. Sometimes a row of sheet piling is driven about the floor to help its sustaining power.

The use of the concrete is to have a solid brace between the heads of the individual piles. On this flooring the masonry is constructed.

If the water exceeds twenty-five feet in depth caissons will have to be substituted for coffer-dams. Caissons are of two kinds—floating and pneumatic. Floating caissons are made up of large timbers in the form of a huge box large enough to build the pile or structure inside. It is floated into its position for sinking and the masonry is started. As the masonry progresses the caisson sinks and more timbers are added to its sides. The foundation for its bottom to rest upon is prepared by divers, but in all cases where these are used there must be but very little excavation under water, and the foundation must be of hard gravel or rock. In some cases iron bottoms are put into caissons and the timber riders are detachable. Caissons of this kind have been sunk in 150 feet of water. The pressure is so great at these depths that the water is squeezed through the pores of the wood and a pump is required to keep the caisson dry. As the centre of gravity rises with each course of masonry, there is sometimes great danger of the caisson tipping over. Pontoons moored and attached to the caisson will aid in overcoming this tendency to tilt. In a bridge recently built by R. G. Reid, in Cape Breton, the pressure of the water burst in the side of a 100-foot caisson and it sunk, or rather filled, as the sides of the caisson were still above the water. Divers were sent down, who filled up the breach with masonry, concrete, and cement, and it was pumped out, when it rose again. Where considerable excavation is required below a great depth of water pneumatic caissons are required.

A pneumatic caisson is only the enlargement of the idea of the diving bell. The caisson is only an inverted box, open at the bottom ; the outside edges are shod and cased with iron, if it be built of wood, so as to give a cutting edge. The roof and sides are made of timber or iron thoroughly bolted and braced, and capable of sustaining the load of the structure. The chamber in the bottom is high enough to allow laborers to work comfortably in it. It is built on land and floated to where the foundation is to be sunk. Air is supplied to the chamber by powerful air-compressing pumps. The air pressure increases as the caisson descends, and must always equal the pressure of water at depth of the cutting edge, so as to prevent water entering the air chamber. The descent to the chamber is made through a wrought iron tube built in the masonry. It has at a suitable point an air-lock large enough to pass several men through at a time. This lock is provided with valves, to prevent the compressed air escaping when anything enters. A person enters the air-lock from the outside atmosphere at a pressure of fifteen pounds per inch ; he closes the outside door and then opens the inside one and allows the pressure of the lower chamber into the air-lock, which may be increased to thirty pounds per square inch. Besides this, entrance pipes for conveying the excavated material up are also built in the masonry. A force of men loosens the soil and it is then forced up to the outside atmosphere through these pipes by air pressure. Rocks and boulders have to be taken up through the air-lock. The masonry is continually being built, so as to give the required weight to the cutting edge. When bed rock or a good permanent strata is reached, it is levelled for the final location of the caisson. The inside of the chamber is then filled with concrete. When the caisson is descending great care must be taken to keep it from tilting ; if a boulder is met by the cutting edge it must at once be removed, lest the other edges lower and upset the whole thing. It is extremely dangerous work to be laboring in the chamber. The late Louisville disaster, in which fourteen men were drowned, shows how careful they must be. The men got in a panic, fought to get through the air-lock, allowed the compressed air to escape, and the water rose and drowned them. The air pressure at depths to which caissons have been sunk is very great ; at 110 feet below water it would be fifty pounds per square inch. Men cannot work at greater depths than 100 feet ; it affects a man in the following ways : Increased respiration, increased pulse, extreme pain in the lungs, and sometimes paralysis. At depths exceeding 100 feet dredges have to be used. Caissons have been sunk in Australia to a depth of 175 feet. Great trouble was experienced before the invention of the electric light in lighting the lower chamber, the pressure of the air causing the lamps to smoke terribly.

There are many other methods of sinking foundations.

In India the natives sink cylindrical brick tubes. The soil is taken out by the natives diving with baskets and filling them under water. As the soil at the bottom is taken out the brick tubes sink. The bricks are fastened together with cement and straw ropes. Foundations have been sunk to the depth of seventeen feet in this manner at a cost of only thirty-two cents per lineal foot. Large cylindrical tubes have been sunk in the same manner as a caisson, and then filled with concrete. The foundations for the Tay bridge were sunk in this manner. The largest caissons ever built were those under the Brooklyn bridge ; they are 102 x 168 feet, with a chamber nine feet six inches high. The Brooklyn pier is sunk forty-five feet below high water, and the New York pier seventy-eight feet. They were built of timber and went to rock. The pneumatic caissons under the piers of the Forth bridge are built of iron and are circular ; they are capable of sustaining a pressure of six tons per square foot. They were provided with separate distinct chambers, so as to be loaded with concrete in different places so as to regulate the sinking ; notwithstanding one of them upset and caused endless trouble. The caissons under the Eiffel tower are capable of sustaining four tons per square foot. This pressure is mostly due to the wind's effect on such an enormous height.

Hollow iron piles have also been used instead of wooden ones. A novel way of sinking piles is by a jet of water forced from a steam-pump. This jet plays through a small nozzle at the toe of the pile and keeps the sand in a mobile state. The weight of the pile then sinks itself. In quicksand this is a faster process than by driving with a hammer. Off Cape Henlopen, in the United States, piles were driven with the water jet that could not be driven by the hammer at all. Screw piles have also been used with a large platform attachment to help their bearing surface. Hollow iron piles may be sunk to an enormous depth, allowing the hammer to fall inside of them, striking their solid iron feet. This device is to prevent the pile bending, as would be the case by striking its top. As the pile is driven new lengths are screwed on at the top. Concrete is largely used is foundations. It is composed of broken stone, cement, and gravel, or sand, in proportions of two, one, and three. The cement should be a quick-setting one, as building is commenced immediately in deep foundations, owing to the danger of bursting in and the cost of pumping, etc. Concrete should be well mixed.

# WATER SUPPLY.

By Edward F. Ball, Grad. S. P. S.

*Mr. President and Gentlemen*,—This branch of engineering is yearly growing in importance. Towns which a few years ago relied upon wells and cisterns to furnish water for domestic and mechanical uses are now taking or have already taken the necessary steps to secure a plentiful supply of wholesome water, at such pressure as will enable powerful streams to be thrown over the highest buildings directly from the hydrants without the use of portable fire engines.

The preliminary steps towards securing the necessary appropriations for constructing a system of water-works are usually prolonged and tedious. After much talk and discussion, an engineer is usually appointed to make surveys and examinations and report upon the most desirable system to be adopted, giving estimates of costs, etc. A by-law to raise the necessary amount is then submitted to the ratepayers, and is sometimes defeated once, twice, or even three times, before it is finally carried. In case the town is unable to construct the works, a company may be induced to build and operate them, the town paying an annual rental for the use of hydrants, usually from $50 to $60 per hydrant per annum.

Should the works prove unremunerative the company are the losers; but if they should prove a paying investment and the town should wish to acquire the works, the statutes provide that they can do so by paying the appraised value of the works, which value cannot exceed the actual cost of the works more than ten per cent.

There is a general feeling that towns should own and operate their own works, but in the case of small towns it may be advisable to rent from a company.

If the engineer employed by the town to devise a system of water-works, be a man of large and extensive practice, he will probably advocate a very complete and extensive system, which may be beyond the financial ability of the town to construct. If, on the other hand, the engineer be of limited practice, he may advocate a cheap system, in order that his plans may be carried out.

In the first case the system will, in all probability, be a very safe and economical one to operate, but the interest on the capital expended in its construction may more than counterbalance this. In the second case, although the item of interest will be low, the expenditure in fuel or attendance or both will probably pay interest on the additional cost of a considerably better plant. It will thus be seen that the town should give careful consideration to the operating expenses as well as to the first cost.

While it is a comparatively simple matter to devise a thorough system of works provided abundant means are at the disposal of the engineer, it is not such an easy matter to say just where the line should be drawn between a complete system and one which will barely supply the needs of the town.

The item of first cost is very apt to be the principal consideration of the ratepayers, and cheap systems are too often the result. In such a case it would be far better for the town to rent from a company, for the company would construct works which could be economically operated, and as a rule this means a more reliable system.

### SOURCES OF SUPPLY.

The sources of supply are usually streams, lakes, springs, or sometimes artesian or driven wells. Whatever the source, samples should be carefully collected and submitted to a chemist for analysis. This analysis should state the hardness of the water (both permanent and temporary), as well as the impurities dangerous to health. The hardness of the water is an important consideration in manufacturing towns where large quantities will be used for generating steam.

About two quarts of water from each proposed source should be collected for analysis, and the best vessels for this purpose are the Winchester two quart bottles, with glass stoppers, found in drug stores. Bottles which have contained sulphuric acid are to be preferred, as any trace of sulphuric acid left in the bottle would probably appear in the analysis as a sulphate of some metal, and traces of sulphates do not indicate contaminated water. Chlorine and nitrogen point strongly to contamination from animal or vegetable matters, and for this reason bottles which have contained these substances in any form, as hydrochloric acid, ammonia, etc., should not be used. When no others were obtainable the writer has succeeded by repeated washings and tests by litmus paper in removing the contents of ammonia bottles so that no traces were detected in the analysis. The bottles and stoppers should be repeatedly rinsed with clear water, and finally with the water to be analysed, then carefully filled, sealed, and labelled. If the water be collected from a stream or lake, the sample should be taken below the surface in order to avoid any floating particles.

Samples may also be taken from wells in the town, in order to compare the proposed supply with that in present use. In collecting samples from a pump the handle should not be raised high, as the plunger may thereby be made to travel in an unused part of the barrel, thereby stirring up sediment. Two or three pailfuls should be pumped and thrown away before the sample is collected. In sealing the bottle a piece of cloth should be placed over the stopper, turned down and tied around the neck. The seal should be placed on the knot of the string.

If the proposed source of supply be a stream, the nature of its source and of the land through which it flows must be ascertained, in order to discover any possible source of contamination or the likelihood of any future pollution.

If the stream be a small one, gaugings will have to be made.

In a large stream or river the water near the edges may be polluted by drainage, etc., and it then becomes necessary to locate the intake some distance from the shore, as at Buffalo, and the system devised by Mr. Monro for the town of Niagara Falls, Ont.

In large lakes the water may become turbid after wind storms. This turbidity extends a long distance from shore, and cannot be avoided by extending the intake into the lake. In such cases settling or filtering basins are necessary.

If sewers discharge into the same body of water that the supply is taken from, the intake must be so located as to prevent the sewage from being carried into it by eddies or currents.

The point at which diluted sewage becomes harmless has never been satisfactorily determined.

Dr. Letheby, formerly medical health officer for London, says: "I have arrived at a very decided conclusion that sewage, when it is mixed with twenty times its volume of running water and has flowed a distance of ten or twelve miles, is absolutely destroyed, the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxidation."

Dr. R. A. Smith, in his testimony before the Royal Commission of Water Supply of London, says: "No one has conclusively shown that it is safe to trust to dilution, storage, agitation, filtration, or periods of time, for the complete removal from water of disease-producing elements, whatever these may be. Chemistry and microscopy cannot and do not claim to prove the absence of these elements in any specimen of drinking water."

Dr. Lyon Playfair, of London, remarks: "The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry color on being exposed to the air in reservoirs, or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings."

Small lakes or ponds are often polluted by decomposing vegetable matter. Such matter will decompose very slowly if immersed in ten feet of water, so that if all the vegetable growth be removed for a depth of ten feet no danger need be apprehended.

Lakes and ponds subject to vegetable growths should have their edges deepened and protected by a retaining wall.

Dr. P. H. Bryce, Secretary of the Provincial Board of Health, gives the following rules indicating the purity of water:—

"(1) Water must be clear and entirely free from suspended matter.

"(2) It should be colorless or bluish if looked at through a depth of two or three feet; green waters are not generally hurtful; yellowish or brownish are to be looked upon with suspicion, unless the color is known to depend upon peat or iron.

"(3) Water should be sparkling and bright, showing that it is well charged with air and carbonic acid.

"(4) It should have the pleasant sparkling taste of good water, but no brackish or any other unpleasant or peculiar taste.

"(5) There should be no smell other than the peculiar, indescribable smell which fresh spring water yields.

"(6) It ought to be soft to the touch and dissolve soap easily (that is, not have too much carbonate of lime in it).

"Though it would not be safe to say that any water having these characteristics is absolutely good, yet no water without them can be considered free from objections."

Perhaps the best test for organic impurities, in inexpert hands, is to put one or two drops, or enough to give a pink color, of a solution of permanganate of potash in an ounce vial of the suspected water. The solution should be of the strength of eight grains of permanganate to an ounce of pure water—distilled water, or filtered rain water caught in the open, or the water-works water will do nearly as well if more convenient than the other. If the water be unfit for drinking the color will be discharged or bleached in about twelve hours, and usually the impurity may be seen precipitated at the bottom of the vial. The test is more satisfactory if a similar bottle of pure water be treated the same as the suspected sample and placed alongside it for comparison. *The Pharmaceutical Journal* quotes Heische's simple sugar test for water as follows: "If half a pint of the water be placed in a clean, colorless, glass-stoppered bottle, a few grains of the best white lump-sugar added, and the bottle freely exposed to the daylight in the window of a warm room, the liquid should not become turbid even after exposure for a week or ten days. If the water becomes turbid, it is open to grave suspicion of sewage contamination, but if it remains clear it is almost certainly safe."

If the source of supply be a pond or small lake the water often becomes lowered, leaving a margin exposed to the air. Upon this margin a luxuriant plant growth springs up, decays quickly, and produces foul vegetable muck. This may be remedied by deepening the margin of the lake as before described.

Usually the lowering of the waters will cause the water from the drainage-bed of the lake to percolate more rapidly towards it, so that unless the lake be very small the supply will probably remain sufficient.

In some localities large springs discharging from thirty to eighty gallons per minute are found. Where a sufficient number of these can be collected they will afford a good supply. The impurities of spring water are chiefly mineral in character and not injurious to health.

Driven wells consist of wrought-iron pipes from one and a quarter to three inches in diameter. They are driven into the ground in sufficient numbers and to such depths as to yield the required supply. They are then connected to one common suction main, which should be provided with a sand chamber of ample size and proper construction to arrest the flow of sand and admit of cleaning when required.

The Hyde Park, Mass., Water Co. derive their supply in this manner from sixty-four wells of two inches diameter, varying in depth from twenty to thirty-eight feet, and from this system a supply of 1,000,000 gallons per day can be pumped. The town of Auburn, N.Y., is supplied with water from Owasco lake by a suction pipe twenty-four inches in diameter and 9,830 feet long. This suction pipe follows the contour of the ground, as it would have cost about $50,000 more to lay it to a grade, and to make provision for removing the air which collects in the highest parts of the pipes, a wrought-iron pipe was laid connecting these points with an air-pump, which keeps the pipe free from air and causes the pipe-line to work as an immense siphon.

## SYSTEMS OF SUPPLY.

It is not only necessary that water be delivered in the mains of a town under sufficient pressure to force it to the upper stories of houses; it should have a pressure sufficient to throw streams over the highest buildings directly from the hydrant. The advantages to be derived from such a supply of pure water are manifold :—

(1) The death rate in many places is lessened.

(2) The best-known system of fire protection is secured.

(3) Insurance rates are reduced.

(4) Extra inducement is offered to manufacturers, who are generally wary about investing capital where insurance rates are high, and where the whole outlay may be swept out of existence by a single disastrous fire.

(5) Facilities are provided for street and lawn sprinkling.

Towns are supplied by one of the following systems, which are given in order of merit :—

(1) Gravitation.

(2) Gravitation and pumping, (*a*) by water power, (*b*) by steam power.

(3) Direct pressure, (*a*) by water power, (*b*) by steam power.

### THE GRAVITATION SYSTEM.

The gravitation system consists of damming a stream at some high elevation and allowing the water to flow into the town by its own weight. Lakes may sometimes be utilized in this way. Such a system is manifestly a reliable and economical one to operate, and considerable expense is justifiable in securing such a system. When the additional main, etc., required for a gravity supply necessitates such an expenditure that the interest on the cost greatly exceeds the probable annual running expenses of a pumping system, it may be more judicious to adopt a pumping system. For a town of 3,000 or 4,000 the supply main would cost about $2 per foot. Four miles would cost about $42,000, besides the dam and the land necessary for the reservoir, or a total, say, of $45,000. The interest on this at 5% amounts to $2,250 yearly. The cost of pumping-engines, house, and reservoir or stand-pipe for the same town would be about $16,000, the interest on which at 5% would amount to $800 per year. To this add $2,000 for operating expenses, and the total cost of operating a steam pumping plant will be about $2,800 per year.

It will thus be seen that the gravitation system, although costing $29,000 more than the pumping system, would effect a saving in operating expenses of $550 per year. These figures are only given in a general way, and are not intended to be applied to any particular town.

### PUMPING AND GRAVITATION.

In this system the water is taken from a low level and pumped either by steam or water power to a high level, from which it flows to the consumer by gravity. The contrivance for holding the water at a high level may be a masonry or earthwork reservoir embanked or excavated, or it may be a metallic stand-pipe. In some cases wooden tanks are employed. With a carefully constructed reservoir holding five or six days' supply, and good duplicate water-power pumping machinery and duplicate forcing mains this system, is very little inferior to a gravity supply.

### DIRECT PRESSURE.

This is the cheapest system to construct, and consists in simply pumping the water into the mains, the pressure being maintained by the pumps which must be kept in constant operation day and night. This necessitates the employment of two engineers, one for night and one for day duty, besides a great waste in fuel where steam power is used.

Sudden jars and shocks are inseparable from any system of direct pumping, and these greatly increase the liability to accident to the pipes and machinery. In direct pumping by steam some time is required to get up a sufficient pressure to meet a sudden increase in the consumption of water, as in the case of a fire, and this delay may cost the town more money than the total value of the water-works.

Water power can respond more readily to a sudden demand than a steam boiler can, and is much to be preferred for a direct pressure system. Whenever such a system is adopted, every precaution should be taken to enable the supply to be continued in case of accident to any part of the machinery. To effect this the boilers and engines, and also the suction and forcing mains, should be duplicated, so that either set may be operated independently of the other. The greatest strain comes on the whole system when a conflagration is raging, and at such a time any interruption of the supply would prove most disastrous. Although the question of safety and reliability has usually a secondary consideration with aldermen and ratepayers, the item of expense is a very important one. Perhaps the most forcible comparison may be made in the following way :—

Annual cost of operating a direct pressure system for an average consumption of 150,000 gallons per day :—

| | |
|---|---|
| Coal, 300 tons, at $3.75 | $1,125 00 |
| Attendance, two engineers | 800 00 |
| Salary of superintendent | 600 00 |
| Repairs and incidentals | 300 00 |
| Total | $2,825 00 |

With a stand-pipe or reservoir holding from one to six days' supply, sufficient water could be pumped every morning to last all day and night. The fires could then be banked, the machinery examined and cleaned, and only one engineer would be necessary.

Annual cost of operating a pumping and gravity system for an average consumption of 150,000 gallons per day :—

| | |
|---|---|
| Interest on stand-pipe or reservoir | $500 00 |
| Coal, 225 tons, at $3.75 | 844 00 |
| Attendance, one engineer | 400 00 |
| Salary of superintendent | 600 00 |
| Repairs and incidentals | 300 00 |
| Total | $2,644 00 |

Of course such estimates are very indefinite, and will vary considerably with the price of coal, the pressure at which the water is maintained, and the skill of the fireman, but no doubt can remain as to the economy of an elevated reservoir or stand-pipe holding at least a day's supply.

As before stated, direct pumping by water power is less objectionable, and when electric lights are operated in connection with a direct pressure steam plant, the annual expenses of operation may be less than if an item of $400 or $500 interest on the cost of a small stand-pipe were incurred. If, however, a reservoir or large stand-pipe were constructed, so that the pumping could all be done during the hours the electric lights were operated, a saving would be effected.

It may here be mentioned that the object of this paper is simply to give such information as will enable the reader to report intelligently upon the most desirable system for a small town. No attempt will be made to describe details of construction, as such information can be found in "Fanning's Water Supply Engineering, "Some details of Water-Works Construction," by W. R. Billings, and the descriptive catalogues of various manufacturers of pumping machinery, as The Holly Mfg. Co., Lockport, N. Y.; Henry R. Worthington, New York, N. Y.; The Blake Mfg. Co., Boston, Mass.; The Volker & Felthousen Mfg. Co., Buffalo, N. Y.

### AMOUNT OF WATER CONSUMPTION.

In New England towns and cities the average daily consumption and waste of water is approximately as follows :—

| | | | | | | |
|---|---|---|---|---|---|---|
| Places of | 10,000 | population, | 35 to 45 | gallons* | per head | of population. |
| " | 20,000 | " | 40 to 50 | " | " " | " |
| " | 30,000 | " | 45 to 60 | " | " " | " |
| " | 50,000 | " | 55 to 75 | " | " " | " |
| " | 75,000 and upwards, | | 60 to 100 | " | " " | " |

In small towns and villages the amount of water daily consumed may not exceed ten gallons per head per day, while in large cities it may be as much as 175 gallons. This difference is due to the fact that in villages only a small number of the inhabitants will be consumers, the majority retaining their wells and cisterns; while in large cities nearly all are consumers, and in addition large quantities are used for street sprinkling and various mechanical purposes.

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* All gallons referred to in this paper are the U. S. standard of 231 cubic inches, unless otherwise mentioned.

The daily consumption varies with each month of the year, and with each hour of the day. If unity be taken as representing the average daily consumption throughout the year, the lowest daily consumption may be represented by 0.89 for the months of January, February, and March, and the highest by 1.14 for July, August, and September. The maximum rate of consumption will probably occur about 10 o'clock a.m., and will probably be 1.75 of the average daily supply.

In designing mains and pumps provision must be made, not only to provide for the *average daily* flow, but for the *maximum* rate, which is about double the average rate.

### FLOW OF STREAMS AND RAINFALL.

If the contemplated source of supply be a small stream whose average daily flow is insufficient, a large storage reservoir, holding three months' supply, may be necessary. If the land drained by the stream is hard and impervious, the rain which falls upon it will flow over its surface to the nearest water-course, which, becoming swollen and turbid, will rapidly convey the water away, and the water-course will be left nearly dry. If, on the other hand, the soil be porous, the rain water will be quickly absorbed and will percolate slowly through it to the stream, which will not be so much swollen and discolored, and which will flow comparatively evenly all the year.

It is the office of the storage reservoir to impound the storm waters (which would otherwise escape) and to store them for use in the dry season.

The mean annual rainfall may be taken at forty inches, but during dry years it will be only 80% of this, or thirty-two inches. The available flow of the stream will be about 50% of the rainfall on the land drained by it, or sixteen inches.

The evaporation and percolation from the reservoir may be taken at 5% of the mean rainfall, or two inches, leaving fourteen inches available for consumption. As it is not always permissible to consume the whole flow of a stream, only half this quantity, or seven inches of rainfall, should be relied on.

A safe general estimate of the maximum continuous supply of water to be obtained from forty inches of annual rainfall upon one square mile of watershed, provided the storage equals at least 15% of the rainfall, gives seven cubic feet per head per day to from 13,000 to 15,000 persons dependent upon the amount of available storage of winter and flood flows; or say 750,000 gallons of water daily.

### FIRE STREAMS.

As before stated, the pressure at the hydrants should be sufficient to throw water over the highest buildings, through, say, 250 feet of hose. Assuming the height of the tallest buildings to be seventy feet, an effective pressure of thirty-five pounds per square inch at the nozzle will be required. This will throw a one-inch stream, discharging 154 gallons per minute, to a height of seventy-one feet, and will require a pressure of fifty-four pounds at the hydrants to overcome the friction of 250 feet of two and a half inch rubber hose. The friction in the mains (including bends, valves, etc.) should not exceed ten pounds for moderate distances, so that the static pressure at the hydrant should be about sixty-four pounds per square inch. The head required to give that pressure is 147 feet—say, 150 feet.

To find the static pressure in pounds per square inch, multiply the "head" of the water in feet by the constant 0.434, and to find the head in feet divide the pressure in pounds per square inch by 0.434. The directions for fire pressure given in Fanning's Water Supply Engineering are as follows: "For a really valuable fire service, the *effective* head pressure remaining upon the pipes, *with full draught*, should be in commercial and manufacturing sections of a town not less than 150 feet, and in suburban sections not less than 100 feet."

A consulting engineer to a town council should be very familiar with the subject of fire streams, as questions like the following are likely to be asked:—

"What pressure (or head) will be required to throw a one-inch stream —— feet high through —— feet of hose?"

"What difference would be made by the addition of —— feet of hose?"

It is beyond the scope of this paper to introduce tables of fire streams, but the following rough rules will be useful to remember:—

1. With one-inch nozzles, the loss of pressure due to friction in each 100 feet length of two and a half inch rubber hose may be taken at nine pounds per square inch for an effective pressure of forty pounds at the nozzle. It varies from six pounds for an effective nozzle pressure of twenty-five pounds to eleven pounds for an effective nozzle pressure of fifty pounds.

2. Between effective pressures of twenty-five and forty pounds at the

nozzle, the vertical distance in feet reached by the jet will be about double the number of pounds pressure.

*Example.*—An effective pressure of fifty pounds at the hydrant will give an effective pressure through 200 feet of two and a half inch hose of $50-(2\times 8)=34$ ℔s. at the nozzle, and will throw a stream to a height of about $2\times 34=68$ feet.

### DISTRIBUTING RESERVOIRS AND STAND-PIPES.

After the source of supply has been determined, the next step is to select a site for a reservoir. As before stated, this should be at an elevation of 150 feet above the business part of the town, unless the reservoir is a considerable distance away, when the elevation should be greater. If no higher elevation can be obtained, and the deficiency may be remedied by increasing the size of the supply main. The best material for a reservoir is a mixture of clay, sand, and gravel, in the following proportions:—

| | | |
|---|---|---|
| Coarse gravel | 100 | parts by volume. |
| Fine gravel | 35 | " " " |
| Sand | 15 | " " " |
| Clay | 20 | " " " |
| Total | 170 | |

When thoroughly compacted this will make about 125 parts.

Gravel and sand alone will not make water-tight work, and clay by itself is apt to slip.

When a reservoir is impracticable a metallic tank or stand-pipe, built up of plate iron or steel like a steam boiler, becomes desirable. The following quotation is from Fanning:—

"Many municipalities are situated in slightly undulating districts, where elevated, embanked, or masonry reservoirs of capacity to hold a supply of water equal to five or six days' draught of the town are unattainable. In such places the metallic stand-pipe or water-tower, located on some moderate elevation, or raised on a trestle or masonry tower, becomes a valuable adjunct to the water system, and especially so to the systems of the smaller town and villages, where its capacity ought always to equal a full day's consumption of water.

"The tank stand-pipe has great value in connection with steam pumping-plants unconnected with a large elevated reservoir when compared with direct pressure alone. The ready-filled elevated tank may save a delay in increased volume and pressure of water, that saves also one-half the town from destruction by fire."

Stand-pipes act as cushions to the pumps, and greatly decrease the liability to accident through sudden shocks. In towns and small cities they may also serve as reservoirs, enabling the daily pumping to be done in twelve hours or less.

The reservoir or stand-pipe may be located in three different positions in regard to the pumps.

In the first case, the reservoir is between the pumps and the town, and all water is first delivered into the reservoir, from which it flows to the consumers. In such an arrangement a connection should be made between the forcing-main and the supply-main, so that when the water in the reservoir is drawn off for cleaning or repairs the supply may still be maintained directly by the pumps.

In the second case, which is manifestly not the most desirable arrangement, the pumps are between the reservoir and the town.

In the third case, the town lies between the pumps and the reservoir, and thus has a "head" at both ends. Should the reservoir or stand-pipe be of insufficient elevation to afford the necessary fire pressure, an arrangement should be provided whereby it could be disconnected from the mains, and any desired pressure maintained directly from the pumps.

Following is a list of some of the largest stand-pipes :—

| Location. | Diameter. feet. | Height. feet. |
|---|---|---|
| Wichita, Kansas | 2½ | 150 |
| Danville, Illinois | 3½ | 200 |
| Louisville, Kentucky | 4 | 170 |
| Erie, Pennsylvania | 5 | 233 |
| Burlington, Kansas | 8 | 120 |
| Marion, Kansas | 10 | 140 |
| Great Bend, Kansas | 12 | 150 |
| Crawfordsville, Indiana | 15 | 175 |
| Gravesend, New York | 16 | 250 |
| Lansing, Michigan | 18 | 152 |
| Pensacola, Florida | 20 | 194 |
| Paducah, Kentucky | 22 | 175 |
| Sandusky, Ohio | 25 | 229 |
| Houston, Texas | 30 | 150 |
| Marysville, California | 40 | 80 |

Tall stand-pipes must be securely bolted to their foundations in order to prevent being overturned by the wind when empty. The calculations for determining weight of foundation and strength of fastenings will not be given here, as they are matters to be considered when the final plans are prepared.

Very tall and narrow stand-pipes are enclosed in masonry towers.

## PUMPING MACHINERY.

A separate paper might easily be devoted to this interesting subject, but although the temptation is strong to discuss the relative merits of direct acting and rotative engines and various forms of steam and water valves, only such descriptions will be given as will convey a general idea of the subject.

*Direct Acting Engines.*—This is the style of the Worthington, Blake, and numerous other makes. In principle it is very simple, the piston-rod of the steam cylinder acting directly upon the plunger of the pumps. This style of engine is comparatively cheap in first cost, and for small cities, where the daily pumping would be done in a few hours, is the most desirable. When the pumps have to be operated constantly day and night a more economical engine becomes desirable, and this style of engine is fitted with a crank and fly wheel, and is supplied with one of the well-known forms of steam valves, as the Corliss or Holly.

All engines (except those reserved for fire purposes) should be compound, and if the daily pumping requires eight to twelve hours, a condenser should be added, otherwise it will hardly pay. Pumping-engines should always be duplex double-acting—never single, as these are certain to produce unpleasant jars and fluctuations in the pressure.

Special engines are required for direct pumping. They should be rotative, and must be fitted with an automatic regulator for maintaining the water at constant pressure. The most approved form of this type of engine is made by the Holly Manufacturing Company, of Lockport, N.Y., a good sample of which can be seen at the High Level Pumping Station at Buffalo, N.Y.

*Capacity.*—The capacity of an engine is stated by the number of gallons of water it can pump in twenty-four hours. The usual capacities range from 250.000 to 20,000,000 gallons.

*Duty.*—By the duty of an engine is meant its economy. This is usually expressed by stating the number of foot-pounds of work it will do for every 100 ℔s. of coal consumed under the boilers. With direct-acting compound engines of the Worthington type running but four or five hours per day, the duty will probably be from 20,000,000 to 30,000,000 foot-pounds of work for every 100 ℔s. of coal consumed. With large direct-acting engines, running day and night, the duty will probably be between 40,000,000 and 60,000,000, possibly reaching 70,000,000. With the most improved rotative engines a duty of 100,000,000 to 120,000,000 may be expected, with a possibility of 133,000,000.

Splendid samples of the latter class may be seen in the 15,000,000 gallon and 20,000,000 gallon Holly engines at the Low Level Pumping Station, Buffalo, N. Y., the former of which has developed a duty of 123,000,000.

### WATER POWER.

The horse-power required to pump 1,000,000 imperial gallons or 10,000,000 ℔s. of water per day to a height of 200 feet may be found as follows :—

10,000,000 ℔s. per day = 6811 ℔s. per minute.

6811 × 200 = 1,362,200 ft. ℔s. per minute = 41 h.p.

Suppose a stream flows 30,000,000 imperial gallons or 300,000,000 ℔s. of water per day. In order that this stream should develop the required 41 h.p., the water would have to fall through a distance of $\frac{10,000,000 \times 200}{300,000,000} = \frac{20}{3} = 6.67$ feet. A good turbine will utilise about 75% of the power of the water falling on it, so that the fall necessary to develop the required power would be at least nine feet. In other words, the stream would require to be dammed up ten or eleven feet above its present level.

Pumping machinery should always be duplicated, in order that ample time may be afforded for repairs without interfering with the supply.

In a small town the provision to be made for fire streams requires a larger engine than would be necessary for the daily supply, unless there were a large reservoir at a good elevation. For a town of 5,000 inhabitants the engines, if operating in connection with a stand-pipe, should be proportioned in the following way: If the town be thrifty and growing, provision should be made for an increase of, say, 50% of population, or 7,500. The probable *average* daily rate of consumption would be 300,000 gallons, but the *maximum rate* of consumption will be nearly double this, or at the rate of 600,000 gallons per day. Four one-inch fire streams, discharging 155 gallons per minute, would require 620 gallons per minute, or at the rate 892,800 gallons per day. Adopting the sizes usually made, the engine for the domestic supply would be a three-quarter million gallon one—compound, and if preferred, condensing, although the condenser would hardly pay, as the daily pumping would be confined to a few hours. The engine reserved for fire purposes should have a capacity equal to the maximum domestic rate plus the maximum fire rate of consumption, or 1,500,000 gallons per day, but for a town of 5,000 inhabitants a 1,000,000 gallon high pressure engine would answer every purpose.

If a direct pressure system were contemplated for the same town, each engine should be capable of pumping both the domestic and fire supply, or 1,500,000 gallons per day.

If instead of a stand-pipe a high reservoir, holding from two to six days' supply, could be constructed, two 500,000 gallon compound engines would be sufficient.

## MAINS.

In designing mains such sizes should be adopted as will prevent undue friction.

The following table will give the maximum velocities which should be permitted :—

| Diameter in inches......... | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 24 | 30 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Velocity in feet per second... | 2.5 | 2.8 | 3 | 3.3 | 3.5 | 3.9 | 4.2 | 4.5 | 5.3 | 6.2 | 7 |

The supply-main should be proportioned to carry the fire supply and the maximum domestic consumption simultaneously.

In the case of the town just referred to with a maximum rate of consumption of 1,500,000 gallons per day, a twelve-inch pipe should be adopted.

Dead-ends should be avoided as much as possible, as the water in them stagnates and requires to be frequently blown off.

The smallest size of main permissible in an efficient town supply is four inches, and if six-inch mains can be substituted so much the better.

## HYDRANTS.

Hydrants should be "double nozzle," and should be placed at street corners, not more than 500 feet apart.

Water companies, when negotiating with a town for a rental system, will frequently make an offer to provide a certain number of hydrants not more than —— feet apart. If the interests of the town are not looked after, the company will crowd the hydrants as close together as possible, thereby lessening the length of main.

The consulting engineer for the town should also specify that the hydrants shall not be *less* than —— feet apart.

While referring to rental systems operated by companies, it may be well to caution engineers against attempts at sharp practice on the part of the companies ;—for example, the agreement may state that the engine-house shall be large enough to hold the engines, boilers, condensers, etc. Perhaps in no other part is the condenser mentioned, and when the engineer employed by the town calls attention to the fact that no condenser has been furnished, he will be informed that the company never intended to furnish one !

### GATES.

Gates or valves should be so situated that the water can be shut off from any street or part of a street without stopping the supply of a considerable district.

They should be uniformly located, as at the intersection of the pipe with the side-line of the street, so that should any accident occur in winter, when the ground is covered with snow, no delay may ensue through explorations to find the necessary gate to shut off the water.

### SETTLING AND FILTERING BASINS.

In localities where the supply of water becomes turbid at certain seasons of the year, settling or filtering basins, or both, should be constructed. If the water becomes very turbid, it should be allowed to deposit the greater portion of its suspended matter in a settling basin, and then be passed through a filter. Several forms of filter are in use, the simplest being a tank or well with porous bottom sunk in the soil at the margin of a stream or lake. Similar in principle is a tunnel running parallel with the shore and below the level of the water.

The form of filter most readily adaptable to various situations has a longitudinal collecting main of sewer pipe, to which are connected lateral branches of perforated tile, the whole covered by a bed which may be made up as follows: Coarse gravel about twenty-four inches, fine gravel twelve inches, coarse sand twelve inches, fine sand twenty-four inches; on this may stand six feet of water, the whole surrounded by masonry.

The water enters the basin above the level of the sand, percolates downwards through it, and is collected by the perforated laterals and brought to the collecting main.

Instead of constructing one large filter, two or more small ones should be provided, in order that one may be operated while the other is being cleaned. The following sizes are recommended for various capacities:—

For one-quarter million gallons per day, two beds of 2,250 square feet each.
“ one-half “ “ “ “ three “ 3,000 “ “ “
“ one “ “ “ “ three “ 6,000 “ “ “
“ two “ “ “ “ three “ 12,000 “ “ “

Where there is no distributing reservoir, a low level reservoir to hold a supply of filtered water is advisable. This reservoir may be of sufficient capacity to hold enough water for an emergency, as an ordinary fire occurring at the time of maximum rate of consumption, or it may contain one or more days' supply. If of limited capacity, direct communication should be established between the pumps and source of supply, so that there may be no diminution of the supply owing to the resistance offered by the filter beds.

# THE DRAINAGE SYSTEM IN ESSEX AND KENT.

By Wm. Newman.

In treating this subject the writer will not attempt to go into details, for they will vary with the circumstances surrounding each particular case.

This district is bounded by the River Thames and Lake St. Clair on the north, Detroit river on the west, and Lake Erie on the south.

The rock base of the district is the corniferous formation, which lies almost horizontally. The rock is covered to a depth of about 100 feet with clay, overlaid, here and there, by deposits of drift sands and gravels. Wherever these gravel ridges occur they form watersheds, from which the streams flow to the surrounding bodies of water. In many places the surface of the land is about on a level with the high-water mark of the adjoining lakes, and, as would be expected wherever this is the case, large marshy districts occur, forming a nearly horizontal plane, in some cases many miles in extent. From the borders of these marshes the land gradually rises at an inclination of about two feet per mile, seldom or never exceeding four feet per mile. As is evident, this fall is not sufficient to allow the water to run off quickly, impeded as it is by obstructions of various kinds, such as living and decaying vegetable matter, fallen trees, etc. If left to nature unaided, the water caused by the melting of winter's snow and ice, increased by the heavy rains, would remain on the land till summer's sunshine evaporated it. Here it must remain, covered with its putrescent green scum, to breed mosquitoes and malaria, unless man interposes his skill to assist nature to remove it.

The passing of the Ontario Drainage Act was a boon to the southwestern part of Ontario, for from the passing of this Act the development of the agricultural industries of these countries dates. The Act empowers municipal councils to borrow money, on the credit of the municipality, for the purpose of constructing or repairing drains within that municipality, and charging the same against the lands benefited by the drain ; also to engage an engineer to make surveys, plans, etc., for the drains. When any person or persons wish to have a drain constructed or repaired, they circulate a petition throughout the neighborhood, and, if possible, secure the signatures of the majority of those interested, praying the municipal council to consider the matter. An engineer is usually appointed to examine the locality and report to the council ; if his report is favorable to the scheme, he is asked to make surveys, plans, estimates, etc., apportioning the expense to be borne by the lands benefited and the municipality for the improvement to roads. If the council then adopt the scheme, they instruct their clerk to prepare a by-law to give it effect, and this by-law is published for at least four successive weeks, in one of the local papers, before its final passing. If any party interested thinks he is over-assessed, or that some should be assessed that are not, he must give notice of the same in writing to the clerk of the municipality. Then, in due time, a court of revision, consisting of the council of the municipality together with the clerk and engineer, sit on the case and consider the grievances complained of.

If the drain passes into another township, or another municipality is in any way affected by it, the engineer is required to make out as many plans, etc., as there are municipalities interested. The clerk will serve these upon the proper officials in the several municipalities. Here is where the fun begins, for almost invariably these outside municipalities think they have been over-assessed, and will fight the matter out, either in the courts or by arbitration. So the lawyers get their fingers in the pie, and many municipalities are now paying thousands of dollars more than they would be paying if they had adopted the engineer's report at first. It generally ends in the engineer's assessment being carried out; but people will have their "say" even though they pay dearly for it.

In making the survey the route the engineer is to follow is usually stipulated in the petition sent in to the council. If it is a new drain, running though the woods where there are no traces to be followed, he usually goes over the ground with a compass or transit and chain, setting two lines of stakes, one where the centre of the proposed drain is to be, the other at a distance to one side, depending upon the width he thinks the drain will have to be, but far enough from the centre of it to be safe from disturbance while the drain is being dug, so that the contractor can get his depths from them. The side stakes are placed two or three chains apart, and numbered from "0" up. After setting the stakes, the engineer then takes levels along the line of side stakes, paying particular attention to any sudden rise or fall in the surface. At every few stations he establishes bench-marks along the entire line.

If the drain follows the course of an old ditch the transit is dispensed with, the level and chain only being used. The side stakes are set on that side of the drain where they are least likely to be disturbed during construction. Then the engineer takes the elevation of all the stakes, together with the elevation of the bottom of the drain opposite each stake, and with a tape or rod measures the top and bottom width of the old drain. Then, from the inhabitants he learns, as nearly as he can, the direction of every little watercourse in the neighborhood. After gaining all the information he can in the field, he returns to his office, and from his notes makes out his plans, profiles, estimates, etc. The profile is usually started first, and upon it the grade line is struck in pencil, then an estimate of the cost is made out, and also of the number of acres of land benefited by the drain, together with the respective benefits to each lot. If the engineer finds the cost of the work will be more than the parties interested will submit to, he must reduce the size of the drain; this is generally done by raising the grade line. When at last the grade line has been struck and the depth of the drain at each station determined, the bottom width is settled on from similar ditches which have a proportionate area to drain, but if the engineer should not be aware of any such drain, he can easily determine the width the bottom will need to be by knowing the area to be drained, and allowing $\frac{1}{10}$ inch as the maximum rainfall that will reach the drain in one hour, then applying the formula:

$$D = c.a\sqrt{rs} = c.bh\sqrt{rs} \text{ or } b = \frac{D}{c.h\sqrt{rs}}$$

where $h$ is depth and $b$ the mean width of the drain at the shallowest place, D the discharge in cubic feet per second, $r$ the hydraulic radius, $s$ slope of grade line, $a$ the area of cross-section of drain, and $c$ a numerical coefficient, which varies with the degree of roughness of the bed and other circumstances. As most drains have side slopes of 1 vertical to 1 horizontal, it is easy to calculate, from the above, the width of the bottom. The bottom width will generally be started less at the head, and will be increased where there are laterals flowing into it, until the outlet is reached.

The depth of the drain will depend on circumstances, but in no case should it be less than three feet, to allow the adjoining lands to be underdrained into it.

When the engineer comes to make out the assessment against each particular landholder, the trouble waxes greater. The assessments are small at the outlet and gradually increase towards the head, but the difference between that at the outlet and that at the head seldom exceeds 50 per cent., yet it puzzles some to see why they should be assessed for the construction of a drain sometimes several miles away from them, when, as they claim, their lands remain dry without the drain; but they forget that the water from their lands is continually pouring down and overflowing the low-lying lands near the outlet, unless some provision is made to prevent it.

The county of Essex and the western part of Kent forms a peninsula about twenty miles wide, with Lake St. Clair on the north and Lake Erie on the south. Nearly all this district is covered with a level clay soil, except a gravel ridge varying from one to five miles in width, skirting Lake Erie, then running north-west until it loses itself in the western part of the country. With few exceptions the water runs north from this ridge to Lake St. Clair, or south to Lake Erie. In the northern watershed there are several creeks or "swales," which can scarcely be discerned by the passing traveller, unless it be during the spring or fall freshets. Large drains have been cut through these "swales," some of them twelve to fifteen miles long and three to eight feet deep, and varying from ten to thirty feet in width at the bottom, which, with a side slope of one to one, gives a surface width of sixteen to forty feet. These large drains have smaller ones flowing into them, and often these laterals have still smaller ones flowing into them, the whole forming a regular network of drains nearly as perfect as nature herself could provide ; but, ah ! the cost !

The great failing in many of these systems of drains is that the main drain is not of sufficient capacity to carry away the water as fast as it is brought down to them during freshets. They overflow their banks, giving rise to a great number of needless lawsuits for damages. These drains enter Lake St. Clair through the level marshes along its border ; of course their velocity is much reduced, and they frequently overflow, doing considerable damage to the crops on the low lands ; but to get over this difficulty the earth taken from the drain in its construction is made into dykes or levées to keep the water in the channel until it reaches the lake.

The writer was engaged during a part of the summer of 1889 making plans and specifications for the dredging of one of these drains in the township of Tilbury West. The plan was simple but effective. The length of the channel to be dredged was about three miles, through which two dredge channels were to be cut, each three feet deep and thirty feet wide, one on each side of the old creek channel. The excavated earth was to be thrown up in the form of levées or dykes, one on each bank of the channel. These levées were eight feet wide on top, with a clear space of six feet between the outer edge of the channel and the inner edge of the levée. Where any lateral drain entered large sewer pipes were to be put through under the dyke, and at the inner end of these is placed an automatically acting valve, to prevent the water in the main channel from flowing through upon the adjoining lands, as it would otherwise do during freshets. The estimated cost of the work was about $20,000, but as there were the usual lawsuits the work has not been carried out yet.

To avoid being taxed for one of these large drainage systems, the township of Romney, county of Kent, has resorted to a somewhat novel system for draining a large portion of its lands. The township lies along Lake Erie, and one looking at the map might suppose there would be no difficulty in draining it to that lake, but such is not the case, for along the southern border of the township there is a high gravel ridge from which the water runs naturally over parts of three townships for a distance of twenty miles to Lake St. Clair. Romney was being taxed for outlets across these townships, and to avoid this forever they took the advice of J. C. McNabb, C.E., to cut a tunnel under the gravel ridge to Lake Erie. The distance across the ridge at the point selected is about 7,000 feet. The south end of the tunnel was started on a level with the high-water mark of Lake Erie, and carried back on an inclination of .066 to 100 for 1,300 feet, where a depth of eighteen feet was reached, and here the tunnel proper begins, the first 1,300 feet being an open ditch seven feet wide at the bottom, and varying from ten to eighteen feet in depth. The tunnel is 1,500 feet long, four feet inside diameter, and built of two courses of hard burnt brick laid in cement mortar, and is thirty-eight feet below the crest of the hill. The method of constructing it was simple. They sank shafts about 200 feet apart and tunnelled each way from these. They were very successful in most of them, but in one or two cases they struck quicksand, which caused considerable trouble and delay, but this was finally overcome and the brickwork was completed in the spring of 1890. On the north end a ditch similar to that on the south was constructed. In excavating these approach ditches wheel-scrapers were used, the earth being broken on the south end and kept on an incline, up which the dirt was hauled.

What strikes the engineer most forcibly is the very small carrying capacity of this tunnel when we consider the extent of country that is to be drained into it, namely, about 10,000 acres; now allowing one-tenth of an inch as the maximum rainfall which will reach it in one hour will give about 3,500,000 cubic feet per hour, while the utmost capacity of the tunnel is about 250,000 cubic feet per hour, thus showing that it is altogether too small for the amount of water it is intended to carry.

Another problem now agitating the minds of engineers and land-owners in this section of country is the reclaiming of marshy lands lying along the edges of the lakes and rivers. Frequently the level of this land is not more than a foot above high-water mark. Between the marsh and the lake there is usually a narrow ridge of beach gravel which is broken through in places, so that the lake water can beat in during storms. This ridge prevents the water from getting back readily. The great fertility of the soil and the salubrious climate have induced men of capital to invest in schemes for draining these supposed wastes. Dredges are put in to cut wide, deep channels around the tract to be reclaimed, and the excavated earth is formed into dykes between the channel and the lake. Then large ditches are cut here and there through the whole tract. All the ditches are led to one central drain, at which the pumping machinery is placed, to be used when needed. The cost of making the drains and putting in the pumps varies from six to ten dollars per acre, depending on the area of the tract drained and the kind of pumping machinery used. The cost of keeping it pumped out is fifty to seventy-five per cent. an acre per annum. Several kind of pumps are used. On Pelee Island, where several thousand acres have been treated in this way, they have a wheel with fans on it fitting closely into a sluice, in which it is caused to revolve. The fans lift the water up after the fashion of the old-time water-wheel, but in the reverse order. It is said to work satisfactorily. Where there are only a few hundred acres to be drained, a large endless chain pump is used on an inclined plane like the elevators in a flour mill.

The large ditches are not really needed to carry off the water, but the excavated earth is used to build up dykes to prevent the water of the undrained lands and the lake from overflowing the drained part. The main purpose of the large ditches is to act as reservoirs during sudden freshets, and thus reduce the size of the pumping machinery; for if some such precautions were not taken, the water during a heavy rain could not be pumped out unless we had very heavy pumping works, which is impracticable on account of the expense.

Several thousand acres of land on Pelee Island are now the homes of happy farmers, where a few years ago the muskrat and wild duck were indeed monarchs of all they surveyed. The engineering skill of man has triumphed and bent the elements of nature to his will and purpose, has brought health, wealth, and prosperity to this as well as to almost every other part of the world. Now, instead of producing the green-scummed bog-juice, they produce the rich and clustering grapes from which are made the famous Pelee Island wines.

# PHOTOGRAPHY.

By W. A. Lea.

*Mr. President and Gentlemen,*—The Art of Photography covers so wide a field, from being the means of discovery of stars beyond the reach of any other method of search, through all art and industry down even to enabling the small boy to destroy his clothes and produce stained and spotted caricatures of his friends and relations. So the engineer can scarcely be expected not to add this valuable process to his methods of working, and its use will bring to his attention the widest subdivision of photography, in which there is every variety that can make it pleasant and interesting. In fact, at times this variety becomes somewhat oppressive. This subdivision would include all out-door work, such as topography, buildings, and constructions of all kinds. And there might be included also that branch used in physical research, the main idea of which is to make the noble art into an unbiassed automatic record. But here, as the conditions of light and subject are generally constant or manageable, a few trials will settle any difficulty. But where these are beyond control, and moreover beyond any method of estimation, and of such variety as to occasion the remark that no man has ever taken two similar photographs alike the process is not so easily mastered. And it may be safely assumed that nearly every one connected with this subdivision has several times been on the verge of giving up in despair.

### THE APPLICATION OF PHOTOGRAPHY.

It is used now very extensively by engineers and contractors to convey to their employers accurate information in regard to their work. Negatives of the site are taken before anything is done, and also at regular intervals during construction. On the back of the print might be put, besides the date (which should be scratched on the negative), the number of men employed, state of weather, and any other useful information. These pictures would be most valuable for future reference, and on comparing them the amount of work that a given number of men can do in a given time can be estimated. The photographs are also unquestionable evidence in case of any dispute. Also any part of a work that it was thought desirable to have a note of for personal use could be photographed and the information written on the back. In time this would make a valuable series of notes. And one of the greatest advantages is, that when making a report of progress a photograph would convey more and better information than volumes of written matter. Another application would be to record any mechanical device or arrangement ; as in overcoming some unforeseen difficulty, or in moving any heavy body. There would be no time for a sketch and a photograph could be taken of the most active scene of work, and there would be complete notes and a description of all the tackle, packing, jacks, or whatever the appliances were.

In selecting sites for various constructions, or in representing the nature of the ground to be operated upon, a few photographs would be of great assistance, especially where those holding the decision were not able to visit the site. And so on ; the applications are well-nigh endless. In fact, the engineering department of military science almost depends upon this art, and it is to it that we owe the introduction of its use in surveying. And this is really its most important application. The early attempts in this direction were hampered by crude processes and instruments, but in 1858 Colonel Laussedat, of the French Engineers, brought out a careful summary of the principles upon which successful effort must be based, and since then the idea has been worked at until it is now a method giving accurate results, valuable as an auxiliary to ordinary methods for general work, and with its special applications. For example, to determine compass variations, on a starlight night the camera is pointed approximately in the direction true north, and levelled laterally. After an exposure of several hours the arcs described by circumpolar stars and points in the landscape beneath are clearly shown on the negative, the centre of arcs is found, and the radius perpendicular to the horizon is the true meridian.

## THE PRACTICAL WORK.

The subject naturally divides itself into two main parts, the work done in the field and that done in the dark-room. And in the first part we may consider the apparatus, then its arrangement, and afterwards the exposure.

In considering the apparatus, we might as well follow the natural order and begin with the lens. As our object is to obtain as exact a representation as possible, we shall not have to consider those qualifications sought for in pictorial art. But still we should like to have a fair depth of focus, and as good marginal definition as we can. And as we cannot have any distortion, a doublet lens of the type generally called rectilinear, with a focus of about twelve or thirteen inches, would probably be the most suitable. A lens of the wide angle type is useful for a building in a confined situation, or if from the same spot a larger extent of country is required than given by the other. A wide angle lens used on a plate smaller than it is intended to cover gives more accurate pictures for this subject than one of narrower angle on the same sized plate. In the case of near objects, however, where there is some distance between different planes in the picture, the appearance to us is likely to be what we call exaggerated perspective. The lens is the most particular part of the outfit. No amount of care and good work can make up for the want of definition and brilliancy in the picture given by a poor lens. But now the quality of optical workmanship is about at a standard, so there is plenty of choice.

Modern cameras are very different to what they were even ten years ago. Many new and important improvements have been introduced, and the weight has continually decreased without loss of rigidity, so that one is reminded of the contrast between Puffing Billy and a modern fast passenger locomotive. Many of these improvements are not of much value to those who desire to produce a picture fairly right with regard to tone and composition, etc., but they are important as methods of adjustment for obtaining accuracy. In architectural subjects, and wherever consistent perspective is required, there must be some means of levelling the camera. There are several ways of doing this. The simplest is by looking at the horizon along the tailboard of the camera, front and sideways, and adjusting the base correspondingly by means of the legs. But this is open to the objection that we may not always be able to see enough of the horizon, if any, except perhaps in the North-west. Another plan is to hand a small plumb-bob at the side of the camera. When the camera is level sideways it hangs plumb with its side, and a small scale will show its inclination backwards or forwards. But we would naturally dislike to have loose strings hanging about our apparatus, not to mention the probability of their being soon broken or lost. Besides no method can compare with the use of a spirit-level for speed and accuracy. A small level can be carried in the pocket or camera case, and laid on the tailboard to adjust it. But here we have the risk of leaving it behind or dropping and breaking it, and a greater objection, when the camera is horizontal in one direction it is liable to be thrown out in levelling it in the other direction.

An improvement on this is to use a small circular level which can be placed on any flat part of the base, and by watching the position of the bubble with reference to the centre of the level, the base can soon be made horizontal. The loose circular level is open to the same risk of loss or breakage as the straight, and has a further disadvantage, being usually a brass case with a glass top. The rapid alterations of temperature between the pocket and the open air, or the occasional rays of a hot sun and the camera, case make it difficult to keep the joint tight so there is in most bases a tendency to leakage and the destruction of the level.

Another and perhaps the best method is to have two small straight levels let into the tailboard flush and at right angles to each other, or a small circular level may be used.

Another important feature of a camera is the back, that part of it that carries the focussing screen and the slides for exposure. This should be reversible, to use the length or breadth of the plate as required, and have a vertical and horizontal swing. The vertical swing is the vital point of the back, for it is an essential supposition of perspective that the picture plane be vertical, and this plane contains the sensitive plate. So this is a point which cannot be neglected if the parallelism of vertical lines is to be preserved. In most cameras there is some means of adjusting the upright pieces back and front at right angles to the base, and so when the base is made horizontal the plate is vertical. But it is sometimes necessary to tilt the camera to include the view wished for, and then the distortion of convergence is plainly seen. This can be corrected by utilizing the swing-back to once more render the screen vertical. And what has been said with regard to the use of the spirit-level will also apply here.

It may be stated that in copying a photograph that has been distorted by convergence, the swing-back can be used to produce an equal and opposite error, and so give a result with perpendicular lines.

Most backs have also a horizontal swing. This would be used when it is necessary to bring into focus an object close to one side of the view.

On the front there is usually a rising front by which the lens can be raised in order to include more of the upper part of the view. This will save for a short space the tilting of the camera.

The tripod should be as light as is consistent with rigidity, and as portable as possible. If it is too light, it is liable to vibrate on a windy day; and although this vibration will not be noticeable there will result, a fine indistinctness in the negative, which will be rather irritating to the operator. Also the joints should be of such a nature as not to move during an exposure, whether suddenly, or slowly and imperceptibly.

The three legs are generally connected at the top by a small triangle, into the centre of which a thumbscrew fastens the camera.

More usually now they are sprung into catches on a small turn-table, so that the camera is free to revolve. The ideal connection is some simple form of double-joint, or a ball and socket-joint, thus rendering unnecessary the clumsiness of dragging the legs about in order to adjust the camera. Many devices have been proposed, some tried, but as yet none have come into use.

The ground glasses in cameras are not usually as fine in surface as is desirable; so it will be well to get an old plate and make one. The following method with emery is about the simplest and quickest. The finest flour of emery usually contains grease, so it should first be washed in water made alkaline with ammonia, or washing soda, before separating from the finest particles by decantation. With this product, and a grinder (a flat piece of lead, two or three inches in diameter, filed to a smooth, true surface), a very fine veil can soon be made on the glass, and no more should be formed than is necessary to see the image.

On this very exact focussing can be done without the use of a magnifier. If plates of more than one size are used, it is a good plan to set off smaller sizes on the screen, so that the amount of view included may be shown.

Perpendicular and horizontal lines traced on the screen and passing through the centre are useful as guides to arrangement of the view.

In order to see this image a covering of some sort is necessary to exclude light, so we have the much-ridiculed focussing-cloth. It is inconvenient and undignified at the best of times, and on a windy day the operator becomes an object of pity to all who have the luck to see him in his struggles.

So that there are many devices for controlling this part of the apparatus. It was proposed to do away with the use of ground glass, and estimate the view by various contrivances, termed view meters, the focus being marked on the camera. But it has still remained necessary to see what was on the screen, if good results were to follow, so the cloth remains yet. However, tapes can be attached to one end to fasten it to the camera, or, better still, a sort of sleeve can be constructed with elastic at each end, one end enclosing the camera, the other the head.

Another plan is a pyramidal construction on something the same principle as the bellows, free to move in any direction, with the base at the screen and an eye-hole at the apex. This can be readily made by a series of square frames of thin wire, diminishing in size, enclosed in a tapering sleeve of black cloth, to fit. These are, perhaps, not so convenient for examining the screen as the plain cloth, but with regard to the comfort and temper of the operator they are an improvement on the older plan of putting his hat on the ground and fighting with a couple of yards of flapping black cloth.

The most usual carrier and backing of the sensitive film has been, and is, glass. And this is now made so free from spots and flaws that its weight is about the only drawback to its use, in these days the plates being, undoubtedly, the heaviest part of the outfit.

So, for some time back, attempts were made to find a substitute. The first practically used was paper of a very even texture, in cut sheets or in rolls, unwound and exposed in a holder devised for the purpose. But no paper could be made that would not reveal its texture in the resulting print, and, in spite of oiling, printing was rather slow, and the best substitute yet made use of, a film of celluloid, has more faults of its own than has the substance it was introduced to supersede.

The most valuable and extensively-used process now outside of the ordinary glass plate is that of Eastman's stripping film in conjunction with a roll-holder. A thin layer of soluble gelatine is interposed between the sensitive insoluble film and the paper support, so that after development this film, now containing the negative image, could be transferred to any support chosen, usually a sheet of transparent gelatine. The manipulations are not difficult if care be exercised, and the resulting negative is clear, transparent, flexible, of only one-fiftieth the weight of glass, and free from the risk of breakage. It is reversible, and easily touched up, though these are not so important, except for photo-mechanical processes. The most valuable point about the roll film is that, as now arranged, forty-eight consecutive exposures can be given with the one holder, so that all the delightful process of changing plates in the corner of a damp cellar or of a tent by the confusing light of a little smoky ruby lamp, with all the attendant risks of fog, dust, and mixing up of plates, is avoided. But still there is opportunity for exercising care in the use of the roll-holder. A mistake is easily made in the winding, and in order to avoid giving a double exposure, or winding up a portion unexposed, it is usual to form a fixed habit with regard to the winding, either immediately before or after the photograph is taken. It is a good thing also, as often as is convenient, to draw out the slide and mark each end of the exposed part with a pencil as a check in cutting up. This, of course, is done in complete darkness.

Where only a few pictures are required at a time, the roll would give place to the single plate, as there is waste of material and inconvenience in cutting off exposures. The most common form of carrier is the ordinary double-back, as it is called, containing two plates back to back. There are also various appliances for carrying and exposing a dozen or more plates, but these have not been much used since the introduction of the roll system. The backs, or slides, are also made of thin metal, to economise bulk, and a single carrier in the form of a paper envelope is used; but this would have the disadvantages of being too easily affected by moisture and of affording no protection to the plate.

We might close this part of the subject with the mention of a few details.

In some cameras, when racking back for a short focus lens, the front moves instead of the back, so that the tailboard is liable to project in front and cut off some part of the picture; it is as well to look out for this when choosing a camera.

There are devices in front of cameras, generally something like a turntable, to change one lens for another, and in these cases the lenses remain attached to the front when the camera is folded together; but it will be found safer and better in every way to have flange adapters if the lenses do not fit the same flange, and a small lined box into which they fit.

In order to use only the rays passing through the lens in the neighborhood of its centre, the smallest diaphragm consistent with exposure should be used; and a simple drop-shutter is necessary, as even with the smallest stop the exposure is often quicker than can conveniently be given by hand.

# FREIBERG SMELTING PROCESS.

By G. R. Mickle, B.A., Grad. S.P.S.

To the smelter the Freiberg Smelting Works offer a rich field for study, owing to the complicated nature of the ores which are smelted there and the consequently numerous processes which must be employed in order to separate the various metals. The following ores, which are brought from the mines in Saxony, and also from foreign countries, principally Sweden, Chili, Peru, Bolivia, Australia, etc., come under our consideration :

(1) Ores with 30 per cent. and more of galena.

(2) Ores with less than 30 per cent. of galena.

(3) Quartz, or spar ores, with 0.03 per cent. ag. containing pyrites, sulphur under 10 per cent.

(4) Pyritical ores with more than 0.4 per cent. ag.

(5) Sulphur ores with 25 per cent. and more of sulphur.

Copper ores only in very small quantities.

Arsenic ores with over 10 per cent. arsenic.

Zinc ores with over 30 per cent. zinc.

The galena from the mines here contains, as impurities, iron pyrites, arsenic pyrites, zincblende, copper pyrites, antimony, bismuth tin, cobalt, nickel.

The ores are weighed in quantities of 200 lbs.; the accuracy of the weighing varies from 10 lbs. with ores containing 0.01 to 0.5 per cent. silver to $\frac{1}{50}$ lb. with ores containing 50 per cent. and more of silver. From every 200 lbs. an assay is taken for the smelting and mining office, and also one for reference in case of dispute ; from this assay quantity the percentage of moisture is first determined, and from tables the dry weight is read off and noted.

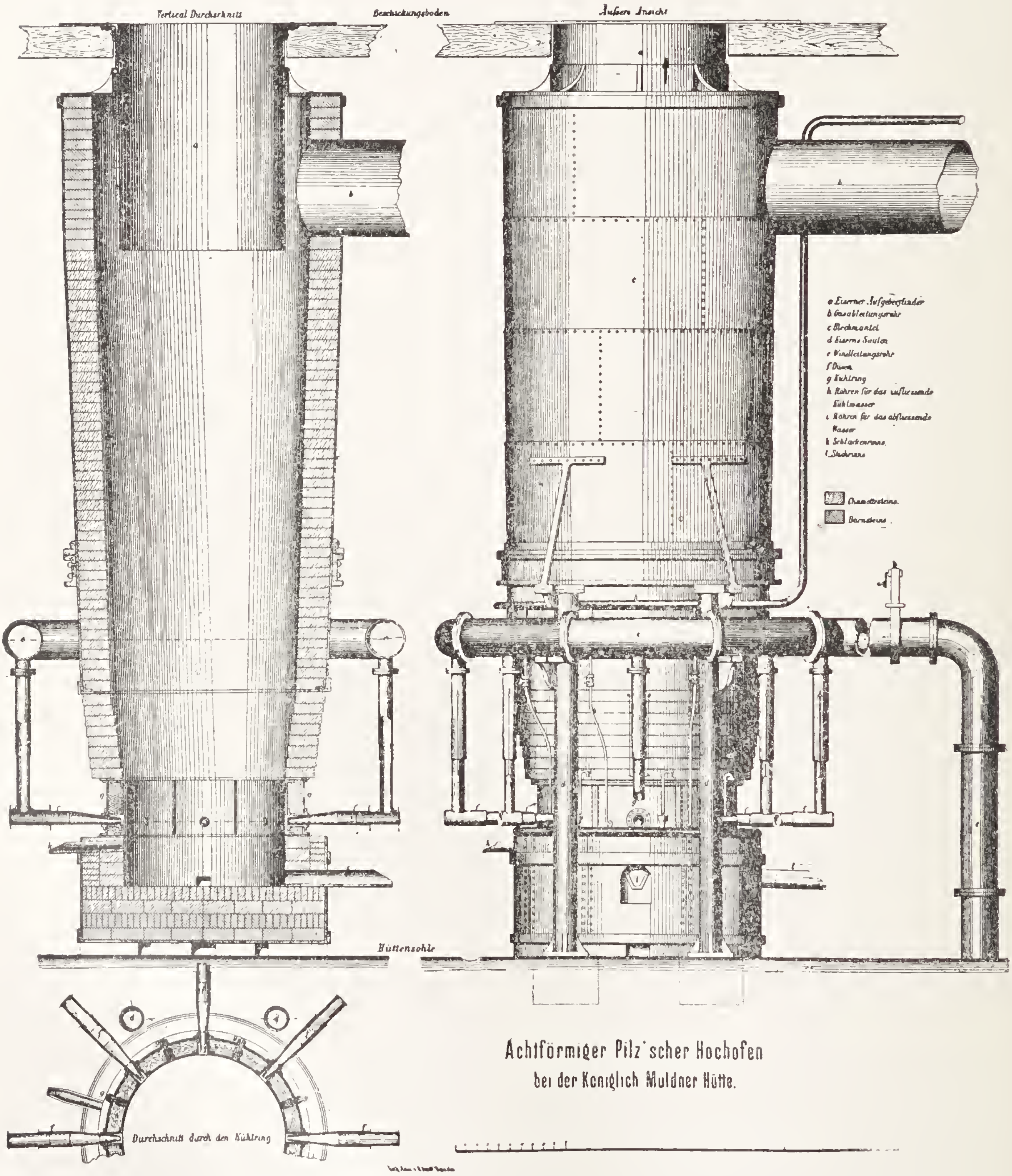
On looking at the tables of the processes the members of the Society will probably feel alarmed, but in order to simplify matters only the lead process, including the winning of gold and silver, also bismuth, will be considered in this paper.

The ores which are delivered in powdered form are roasted, in order to partially remove the sulphur and arsenic, till they contain from five to seven per cent. sulphur, and to bring the ores into a suitable shape for the blast-furnace, that is, into lumps. This roasting takes place in furnaces, the construction of which is seen from the plan. The construction of this furnace allows an economical use of fuel, in that the ores gradually approach the source of heat.

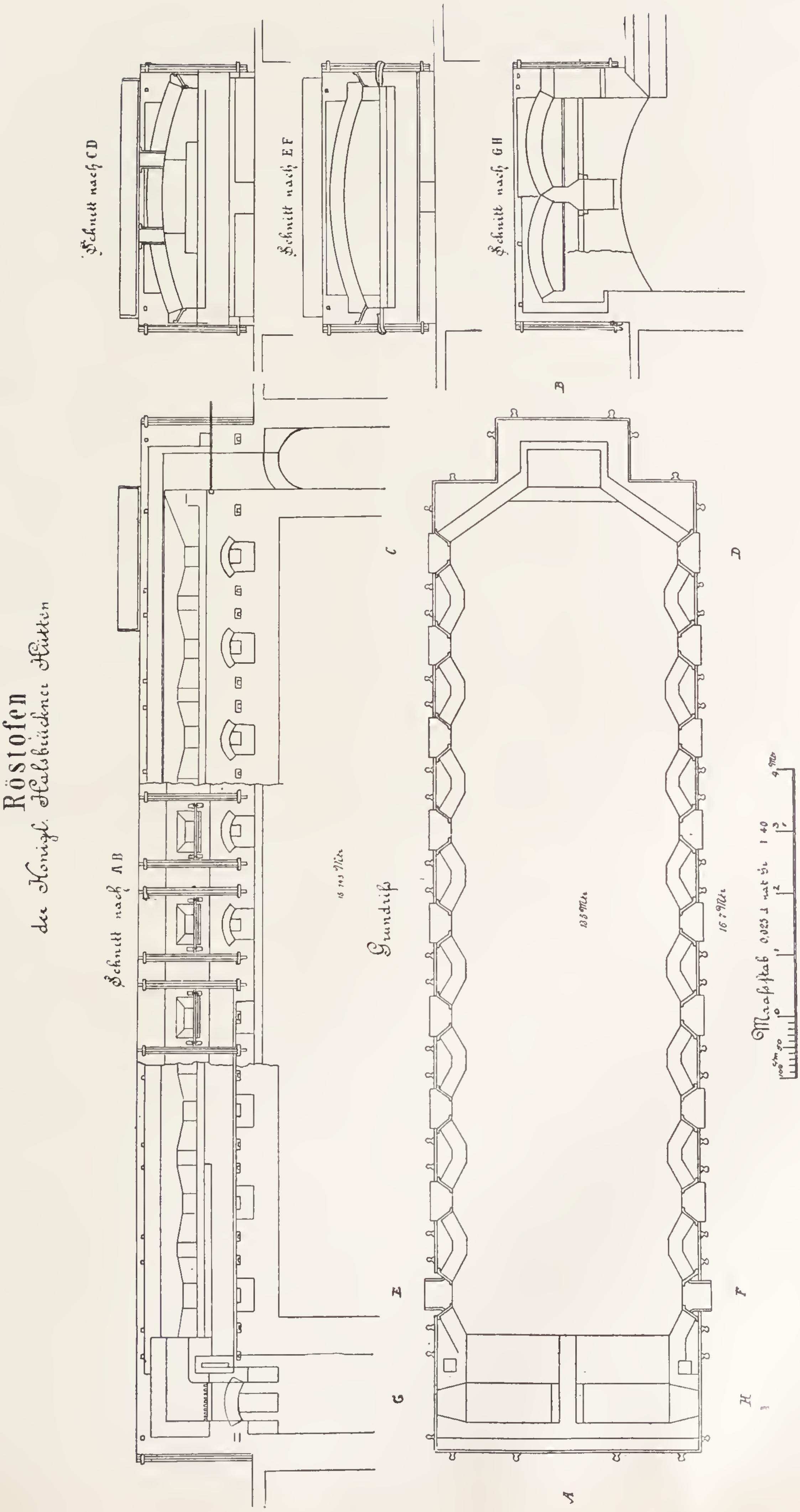
| ORES. | PROCESS. | RESULT. |
|---|---|---|
| 1. Schlach sulphur ores | In Gerstenhof's furnace | Roasted pyrites, flue dust, sulphur dioxide. |
| 2. Lump sulphur ores | Roasted in kilns | Roasted pyrites, flue dust, sulphur dioxide. |
| 3. Sulphur arsenic ores | Smelted for red glass, and residue roasted in kilns | Raw red glass, roasted pyrites, sulphur dioxide. |
| 4. Raw red glass from 3 | Melted with sulphur | Red arsenic glass. |
| 5. Arsenic ores, poor in sulphur | Roasted in reverberatory furnace | Residue, raw arsenious anhydride. |
| 6. Raw arsenious anhydride from 4 | Sublimated | Arsenic meal, white glass. |
| 7. Zinc ores | Roasted in kilns | Roasted zincblende, sulphur dioxide. |
| 8. Zincblende from 7 | Ground and roasted | Zinc, zinc dust, residue. |
| 9. Lead ores, roasted pyrites, residue from 5 | Roasted in furnaces | Roasted ore, flue dust. |
| 10. Roasted ore from 9, residue from 8 | Smelted in blast furnaces with slag from some work-factory, residues, etc. | Unrefined lead, speises, lead matte, slag, flue dust. |
| 11. Unrefined lead from 8 | Liquated | Copper residue, liquated lead. |
| 12. Liquated lead from 11 | Refined | Different scums, refined lead. |
| 13. Refined lead from 12 | 1st. Pattinson's process<br>2nd. Parke's process<br>3rd. Cupelled<br>4th. Further cupelled | Lead, litharge, litharge and residue, impure litharge, separation silver. |
| 14. Litharge and residue from 13 | Worked in the wet way | Bismuth. |

| | | |
|---|---|---|
| 15. Impure litharge from 13 | Returned to 10 | |
| 16. Separation silver from 13 | Separated | Gold, silver, copper sulphate. |
| 17. Scums from 12 | Smelted | Hard lead. |
| 18. Speises from 10 | 1st. Smelted<br>2nd. Roasted in furnaces<br>3rd. Roasted again | Speises. |
| 19. Lead matt from 10 | Roasted in kilns | Roast matt, sulphur dioxide. |
| 20. Roast matt from 19 | 1st. Roasted in heaps<br>2nd. Smelted in blast furnaces, with slag from 10 | Unrefined lead, copper matt, slag. |
| 21. Unrefined lead from 20 | See 11 to 16 | |
| 22. Copper matt from 20 | 1st. Roasted in kilns, or heaps, or both<br>2nd. Treated in reverberatory furnace | Concentrated copper matt. |
| 23. Concentrated copper matt from 22 | 1st. Stamped and roasted in reverberatory furnaces<br>2nd. Dissolved in sulphuric acid<br>3rd. Copper sulphate from 16 added. | Lead and silver residue, copper vitriol. |
| 2 . Lead and silver residue from 23 | See 10 to 23 | |
| 25. Slag from 10 | Used in 10 and 20, and then thrown away | |
| 26. Flue dust from 10 | Used in 5 | |
| 27. Sulphur dioxide | 1st. Head chamber process.<br>2nd. Purification and concentration. | Sulphuric acid. |

The course of work is as follows: On each hearth there are always charges of 3,000 lbs. each. The last charge next to the fire bridge, which is in a semi-molten state of such consistency that one can draw it out with a hoe-shaped instrument, is drawn out every two to six hours, according to the ore; the next charge is then transported on into the space left vacant, and so on the whole length of the hearth. This transporting requires a certain amount of dexterity, and is somewhat tedious, as the whole amount of ore has to be moved by means of an instrument about twelve feet long resem-



Achtförmiger Pilz'scher Hochofen
bei der Königlich Muldner Hütte.



Röstofen
der Königl. Halsbrückner Hütten

bling a spade with a flat blade, which is thrust through the openings seen in the side of the furnace. Eight men are necessary to work the furnace, four on each side. The gases of combustion and smoke, after passing over the whole length of the hearth, escape through an underground canal into a series of chambers of sheet-iron, where they cool off and deposit the flue dust. This flue dust, which consists principally of arsenious acid with 10 to 25 per cent. lead and 0.01 to 0.02 per cent. silver, is cleared out from time to time, and used to manufacture arsenic meal and white arsenic glass. From the condensing chambers the smoke escapes finally into a high stock.

The roasted product from this furnace is allowed to cool, and then broken into lumps about the size of the fist, and taken to the blast-furnace. It is at present a mixture of metallic oxides, more or less undecomposed ore and sulphates, together with earthy components and lead silicate. The object of the blast-furnace is to bring the difficult reducible metals, such as iron and zinc, and also the earthy components, into the slag, to reduce lead oxide to metallic lead, to separate out and reduce lead silicate by means of ferrous oxide, to collect the undecomposed sulphates in a matt, which takes up the copper. So at the end of the process it should stand so:

(1) LEAD, with *silver*, *gold* (traces of copper, tin, arsenic, antimony, bismuth, iron, cobalt, nickel).

(2) MATT, with nearly all the copper, also small quantities of gold and silver.

(3) SLAG, with iron, zinc, and earthy components.

The construction of the blast-furnace can be seen from the plan. The work of charging is carried on at the mouth of the furnace, and the charge is always placed at the sides and the coke in the middle; otherwise the charge, owing to its greater specific gravity in comparison with the coke, would move downwards too quickly; the friction at the sides tends to counteract the difference in specific gravity; when, however, the charge is difficultly fusible, coke is also put at the sides.

The horizontal section becomes greater towards the top, the diameter at the bottom being 1.4 metres, and at the top 2.0 metres. The small dimensions of the hearth allow a concentration of heat, the injurious effect of which, on the walls of the furnace, is counteracted by a cooling ring, in which water circulates, and the widening of the furnace towards the top diminishes the velocity of the escaping gases, and thereby the formation of flue dust, and also prevents the deposit of amorphous or crystalline formations on the upper part of the furnace through sublimation, as the charge on its downward way rubs them off. The temperature in front of the blast is 1300° C, and the effective heat is 40 to 45 per cent., a much more favorable result than in the roasting furnace, which only gives an effective heat of 10 per cent.

The quantity that passes through the furnace is 6,000 to 7,000 tons in twenty-four hours; ore and slag are in equal proportions; the relation of coke to charge is about one to ten.

There are two tap holes for the slag, which are tapped alternately; the slag is thus kept running continuously; the plugging is effected with clay. The tap opening for the unrefined lead and matt is at the bottom of the sump, and is tapped about every four hours, or as soon as the matt begins to come out the slag opening.

The mass is run off into a receiver, and settles itself according to its specific gravity, the unrefined lead of course underneath, and the matt on top. The matt hardens first, and while the crust is forming the workmen suspend a stout iron hook in the matt, and when the matt is sufficiently solid it is raised by means of a crane, and the unrefined lead which has remained molten is cast into pigs. The matt is melted several times more with the slag, till it is rich in copper, and then it is used in the manufacture of copper vitriol. The slag is put through the furnace several times more, till it contains only 0.015 per cent. silver and 2 per cent. lead, and then it is thrown away; small quantities are used as building stone.

When the blast furnace is in normal working order, one must be able to see the glowing coke through the openings for the wind blast, and the slag should flow off rapidly without spurting.

When the working order is bad the slag flows thickly, on account of too low a temperature, or it runs too quickly and spurts, and the matt flows off with the slag. The working order can be bad from various reasons; for instance, when too little coke is used; this can be recognized from the dullness seen on looking through the tuyers; as a remedy they shut off the wind on one side and put in more coke at the mouth, then open again and shut off the wind on the other side: or the working order can be bad when bears are formed in the furnace, that is, deposits consisting chiefly of iron, but which take up gold and silver in considerable quantities, and interrupt the course of the furnace; the iron should go into the slag, but when the temperature is too high, or the reducing action too strong, the iron is reduced; as a remedy litharge smelting is resorted to, or slag rich in copper is added to the charge.

The furnaces remain continuously in blast for about two years or more without repair. During the influenza epidemic one furnace, which had been running more than two years, was allowed to cool off owing to scarcity of workmen; it was still found to be in good condition.

A newly-built furnace is first heated with wood, then coke, followed by light charges of ore; after about four hours the slag begins to flow, and the normal running order ensues.

The unrefined lead from the blast-furnace contains silver, gold, copper, arsenic, antimony, zinc, tin, bismuth, iron, cobalt, nickel.

In order to get rid of the copper, also traces of cobalt, nickel and iron, it is taken to the liquation hearth, that is, a slightly inclined hearth with sump in front. The lead, in the form of pigs, is placed on the hearth and heated at low temperature; lead being more easily fusible than a mixture of copper and lead, flows down into the sump, where it can be tapped and run off into moulds; the whole amount of copper, together with iron, nickel and cobalt, and also a portion of the lead, remains unmelted on the hearth. This process lasts three hours, and 7,000 lbs. are worked at one time.

The products of the liquation hearth are lead, with .07 per cent. of copper; the residues, copper 85 to 95 per cent., with silver .0.3 to .04 per cent., nickel and cobalt.

### REFINING.

The lead is next refined in a reverberatory furnace in order to get rid of tin, arsenic, and antimony, and the process consists in allowing a current of air to play on the surface of molten lead; the impurities rise to the top, and are skimmed off continuously by means of a piece of wood speared on the end of a long iron instrument, and the workman gently rakes the surface.

Twenty-one tons are brought in in one course of refining. As soon as all is in a molten state the blast is brought to play on the surface, and the impurities form a scum on the top; the first impurity that appears is the tin scum: it is an infusible, powdery substance; then comes a yellowish scum of arsenic; then greenish-black antimony scum; finally a litharge-like scum, which gradually passes over into pure litharge, and the lead assumes brilliant rainbow-colors.

The refining lasts from seven to ten days. When it is finished the lead is run off through a gutter into moulds. The inside of the furnace, which is made of clay, must be repaired after every process, as the clay is eaten away where the surface of the lead was. The tin scum and the litharge like scum are used in the manufacture of hard lead, that is, a lead containing antimony and tin; the other scums are smelted over again in the blast furnace.

The refined lead, when it is not sufficiently rich for cupellation, is given over to the Pattinson and Parkes' processes for the purpose of enriching in silver. By the means of Pattinson's process we obtain a rich lead which has from 1.5 to 2.0 per cent. silver, and a poor lead with only about 0.1 per cent. silver, which then undergoes the Parkes' process.

The Pattinson process is founded on the fact that when lead containing silver is melted and allowed to cool the crystals which are formed are poorer in silver than the liquor. For this purpose a battery of nine iron kettles are employed.

Every kettle has a firing for itself, and every two or three a chimney. The crystals are taken out by means of an enormous spoon with perforated bottom, and always go towards one side while the liquor goes towards the other. The percentage of silver in each kettle is daily determined by means of assays. When fresh lead is added, it must go into the kettle which has a corresponding percentage of silver. Two-thirds of the contents of the kettle are removed as crystals into the next kettle.

The work of dipping out the crystals is performed by two men, a third attends to the firing. The operation of dipping is long and exhausting; in this respect it compares unfavorably with the Parkes' process.

As already stated, Pattinson's process gives two products, a rich and a poor lead. We will first follow the poor lead. It contains 0.08 per cent. silver, and comes to the Parkes' process, which consists in extracting the silver by means of zinc, zinc having a greater affinity for silver than for lead. There are three cast-iron kettles, two large ones and a small one in the middle. About twenty tons of lead are brought into the two large kettles; then they are heated to the melting point of zinc, and sheet zinc is put in and stirred round, the zinc takes up the silver and rises to the top as scum; it is then allowed to stand till a crust is formed at the sides, the scum is skimmed off and placed in the small kettle in the middle, which is also heated; here a scum is again formed, which is removed and distilled; the lead comes back again into the large kettles. This process is repeated till the percentage of silver in the lead is only 0.001. When the percentage is originally 0.1, three applications of zinc of 350 pounds at a time are sufficient. The zinc scum from the second and third application, as it is not fully saturated with silver, can be used again, together with fresh zinc. The lead from the two large kettles, which is now free from silver but has acquired a small quantity of zinc, is run by means of a siphon into a refining furnace of the same construction as the ones previously used; the zinc rises to the top and is skimmed off. When litharge begins to come the process is finished, and the lead, which is at last almost perfectly pure, is run off into pigs and sold.

The distillation of rich scum takes place in a graphite crucible, with a receiver at the side to catch the zinc dust. The products are rich lead for cupellation, zinc, zinc dust, and residues containing zinc.

### CUPELLATION.

The rich lead from Pattinson's process, containing about 1.5 per cent., is cupelled. That is an operation that consists in blowing on the surface of melted lead; the lead is thereby oxidized and forms litharge, and the silver remains behind. The furnace, which is of oval shape, with fire at the side, has in front an opening through which the lead oxide or litharge flows. At the back are two tuyeres so inclined to one another that their streams of wind intersect in the centre of the furnace. The whole furnace is covered with a massive lid, which can be moved backwards and forwards. The inside of both lid and furnace is lined with fire-brick. The method of proceeding is as follows: Ten tons of rich lead are put into the furnace, the lid is put on and it is gently fired at first; when the lead is all melted the firing is increased. After about sixteen hours a scum rises to the top; then the blast is turned on through the two tuyeres, and the litharge begins to flow through a narrow channel made by the workman in the wall of litharge that is formed all round the furnace, only a small space in the middle remaining open; the litharge is run off into receivers, put through a fanning mill, and then is sold. This oxidizing process is continued till the percentage of silver is between seventy to eighty per cent., and lasts about 200 hours. Of importance in this process is the temperature. When the temperature is too low the lead becomes too thick, and when the temperature is too high there is a loss of silver; one should be able to see the middle of the lead bath; towards the end of the process, however, the temperature is made very high and the blast is increased. When the cupellation is finished, the rich lead is dipped out into moulds and the residue is cooled off with water and broken out.

This rich lead, containing about eighty per cent. silver, is put in another exactly similar furnace of smaller dimensions, and the process is repeated; a litharge containing bismuth rises to the top and is skimmed off. When the process is finished, the surface of the silver has a peculiar greenish shimmer and there is no litharge to be seen; an assay of the silver is taken in a spoon; it should be white without yellow spots and should also swell out on cooling. The silver is dipped out into a tank containing water in order to get it into a convenient form for the separation from gold. The bismuth in the litharge, which amounts to about six per cent., is extracted in the wet way.

### SEPARATION OF SILVER AND GOLD, ALSO PLATINUM.

The amount of silver separated from gold in Freiberg yearly amounts to about 100,000 kg.; in value, according to the present price of silver, about $3,300,000. It is therefore an important operation.

The separation is effected by means of concentrated sulphuric acid (of the strength 66° Beaumé). About 1,000 ℔s. of granulated silver are put into a cast-iron kettle, then about twice the amount of sulphuric acid is added, and it is gently heated at first on account of the vigorous evolution of sulphurous acid. The silver is dissolved, while the gold remains behind; the kettle is stirred from time to time with an iron rod.

When the hissing noise is no longer heard the silver is all dissolved; it is allowed to cool off and stand about ten hours, in order that the fine particles of gold may settle to the bottom; the solution is then somewhat diluted to precipitate any lead that may be present, and put into wooden tanks lined on the inside with lead, and into which steam is conducted. The silver is precipitated by means of sheet copper (for 100 parts silver thirty-two parts copper) till it no longer gives a precipitate with salt; it is then allowed to clear, and finally the silver is taken out, pressed in a hydraulic press, and fused in a graphite crucible in lots of 1,200 ℔s at a time.

The undissolved gold which was left in the iron kettle is, however, by no means pure enough. It is treated with boiling water, which dissolves out any sulphate of silver and copper which are present, then again boiled with sulphuric acid and washed out. This operation is repeated several times, but beyond a certain point the silver is not dissolved. In order to further remove the silver, it is gently heated several times with acid sulphate of soda, and the sulphate of silver which is formed is dissolved out with water. The gold, however, still contains a small quantity of platinum, which makes it hard and unsuitable for many purposes. In order to remove the platinum the gold is heated with saltpeter; platinum, together with a minute portion of the gold, go into the slag and can be extracted. The gold is finally fused with borax in a graphite crucible, and is at last a mercantile product, containing in 1,000 parts 997.5 parts gold.

# MODERN COPPER SMELTING.

By G. D. Corrigan, Grad. S. P. S.

*Mr. President and Gentlemen*,—It is not the intention of this paper to go into details of smelting, but only to outline some of the more striking points; and since we are not at present concerned with the mining of the ore, we may begin our subject by taking up the process of smelting as begun at the top of the shaft. Here we have an inclined track on which is carried the ore, varying in size from one to one hundred pounds. Next it is broken either by spalling or passing through a crusher, and the proper size to which it must be broken depends much upon the character of the ore. If it be free from rock matter, the largest size, upon breaking, should be that which will pass through a three-inch ring; while if the ore be silicious, it will be necessary to break it still smaller. Among metallurgists it is as yet an unsettled question as to whether hand-spalling or machine-breaking is the better, considered financially. The relative merits of the two may be put thus: "In hand-spalling there is by far a smaller quantity of fines, while the machine will crush the ore at a smaller cost. Now this last consideration may appear to be the ruling one, but in machine-crushing the proportion of fines become large, from fifteen to twenty per cent., and becomes an increasing source of trouble as to its disposal, as will be seen further on. And it will often appear that hand-spalling, though at first more expensive, is in the end advantageous. The crusher used is much the same as that used for stone-crushing, but requires to be run much faster, especially if the ore is damp. A crusher with a jaw opening of fifteen by nine inches, making 230 revolutions per minute, will, with sufficient power, give a capacity almost unlimited. Where the crusher is used the car which contains the ore drawn from the mine is raised by an automatic engine, so that when it reaches a point directly over the crusher the bottom drops, the ore falls into the crusher, and the car at once descends the shaft again. After the ore is crushed it drops into a revolving barrel-screen made of punched boiler-plate, about eight feet long and thirty inches in diameter, placed below the crusher, and is made to revolve eighteen to twenty-five per minute, and has a slope of about one inch to one foot. By means of this the ore is separated into three sizes, the upper five feet of the screen having holes of one inch in diameter punched in it, and the lower three feet holes about two inches. All that comes through the first part is called fines, that through the lower part raggings, while the remainder comes out at the end. Hand-cars stand on tracks below this screen so as to catch the ore which is there culled. The relative percentage of each class separated in this manner is in about the proportion of twenty, twenty-five, and fifty-five. The building in which the operation takes place is elevated about fifteen feet, so that trams are built from it on which the hand-cars are run out to a line of railroad which carries the ore to a system of roast-beds. The ore is dumped from these hand-cars into shoots, which are so placed that the dump-cars are run under them as to catch the ore and prevent all trouble and expense in loading. From here the ore is drawn on an ordinary railroad to the roast-beds, which are generally at some distance from the shaft (about a mile), so as to protect the men from the dangerous and obnoxious gases.

The next part of the operation is roasting or calcination, which signifies the exposure of the ores of metals containing sulphur, arsenic, and other metalloids, to comparatively moderate temperature with the purpose of effecting changes required for their subsequent treatment. There are three different methods of roasting the ore, viz. :—

(1) Heap roasting.
(2) Stall roasting.
(3) Kiln roasting.

Each system has its merits and advocates; but as the writer's experience only refers to the first, the others will not be treated of.

Heap roasting is the most primitive of all, and when properly arranged grounds are chosen and good superintendence is given, it is by all means the cheapest method of calcination of raw ores. In laying out a roasting ground two important features to be considered are, first, the direction of the prevailing winds of the locality, and, second, the elevation, slope, and drainage of the ground. The first precaution is necessary in order to protect the works from the immense clouds of sulphur fumes, so that they shall not be distributed among the workmen. This is a matter of much importance, not only to the workmen but to the surrounding country, if it be an agricultural one, since the sulphurous acid is very injurious to vegetation. The grounds should be protected from inundation, and should be well drained; where a side-hill can be chosen, it often saves much expense.

A long line of trestle-work is built up for running the loaded ore cars to the beds, and by gaining this elevation and using dump cars very little handling is necessary; then, by having a lower track, the roasted ore may be reloaded on the cars beneath without much trouble. The area for roasting-beds depends much upon the capacity of the smelter. The piles are generally forty feet long, twenty-four feet wide, and six feet high, containing 240 tons each, and to furnish 100 tons per day thirty-five heaps will be necessary, requiring an area of 75,000 square feet of roasting ground. The heaps are formed in a single line along beneath the trestle-work.

To prepare the ground it is necessary to remove all stumps, stones etc., and also the top soil, while the space the latter occupied is replaced by broken stone, slag, and tailings from the smelter. The ground should by this means be raised several inches above its surroundings; then over the surface is spread a layer of clay loam, which should be successively damped and rolled several times until it becomes as hard as an ordinary macadam road.

Coming now to the roasting process, the height of the pile will depend much upon the character of the ore; the higher the heap the more fiercely will it burn and the longer it will take to roast; consequently where the ore is rich in sulphur the heaps should be low. The best height for ordinary ore is about five to six feet, under which circumstance it will burn seventy days, the time being diminished or increased ten days for every six inches less or greater than the above height. The area of the pile will have very little influence on the time. The heaps should be thoroughly covered and watched, and combustion kept at the lowest point compatible with safety, the object being to prevent the formation of matte, since the more of this substance that is present, the smaller must be the furnace charge. As stated before, the area of the pile is about 24x40. This is marked out by corner-posts of stone. The surface is then covered to a depth of six inches with fine ore, which prevents the baking and adhering to the ground of the coarser ore, and shows after roasting the boundary between the worthless and valuable material. The fuel is next laid on. Since most sulphide ores will not stand the heat generated by dry hardwood, it frequently happens that a cheaper variety will do; in fact, any old rubbish, as rotten pine, old logs, etc., if dry, answer perhaps the same purpose. The outside border of wood should be of better quality. The usual practice is to lay a course of good cordwood around the outside to a depth of sixteen to eighteen inches, closely packed together; the inside is then filled in to the same depth of poorer wood, closely arranged and packed so as to show a tolerably close and even top, and to prevent ore dropping through. About three chimneys or draught chambers are necessary in a bed of such a size, and they are placed at equal intervals along the centre line. They may be made by nailing four old boards together about six inches wide. Two of the opposite sides should go down to the ground, while the top should be a couple of feet above the ore pile. Three cordwood sticks will serve the same purpose when bound together with wire.

The ore is drawn by an engine and dump-cars up the tram and dumped, then wheeled in iron barrows and put on the pile, the first few barrows being put about the draught chimneys. The main part of the pile is formed of the coarse ore. The heap is formed into a neat pyramid with sharp corners and sides sloping at from 40° to 45°, or as steep as the ore will lie without rolling down, care being taken that the pile does not extend over the outside of the border, which must be kept clear to regulate the draught. The ragging or second grade is next put on, forming a comparatively thick covering. The fines are seldom placed on the pile until after it has been fired. The amount of wood required to burn 240 tons properly will, of course, vary according to the efficient heating-power of the wood, as also upon the amounts of sulphur and bisulphide in the ore, but a fair average is twelve cords, or one cord of wood to twenty tons of ore. Bunches of cotton-waste saturated with kerosene are inserted into the pile here and there on the leeward side of the piles, and a match applied; for a few hours after lighting the pile may be left to itself, in fact it is hardly safe to work around it, since dense fumes of smoke, saturated with pyroligneous acid and the various gaseous compounds of sulphur and arsenic, are almost unbearable and often dangerous. After a few hours the flame will have spread pretty well through the pile, and then is the time it requires attention, since draughts will occur at different points and will soon show themselves by a falling in. It is now the proper moment to put on the fines; but if no signs of uneven burning show, the fines are spread all over the pile. Once well kindled nothing will put the fire out except a dense torrent of water, so all that it is required to do is to keep control of the fire. If matters go all right dense clouds of opaque yellow smoke, smelling strongly of sulphur dioxide, arise from each chimney. The entire surface will be found damp and sticky, while at the vents in the pile will be noticed deposits of mineral sulphur, and often pools of molten sulphur will form. It may be mentioned here that this process at one time formed one of the principal sources of supply of sulphur. To one who has never before come in close proximity with thirty or forty of these roasting piles, the experience might perhaps be very suggestive of other climes, and the sensation can hardly be likened to anything in the natural world. However, like many other things, one gets used to it. The heaps will require constant attention for about twenty days, so as to keep the draught even, as stated before, by covering any spot with fines when it shows too great a draught. After this period the pile needs very little or no attention. The corners and outside and part of the top will not become desulphurized and is used for covering the next pile to be burned; but herein lies the trouble, since it together with the fines from the crusher are an ever-increasing quantity, and give considerable trouble in their disposal. To overcome this it is sometimes necessary to build a kiln in which to roast this surplus.

A constant source of loss from heap-roasting is the amount of copper dissolved by rains and drainage from the grounds, and where precaution is not made against flooding this loss becomes serious. To lessen this sometimes the roasting ground is constructed so that it can be drained to a lower level, where large vats containing old scrap-iron are made to receive the copper in solution, which upon coming in contact with the iron collects upon it in the metallic form. The one great precaution in all roasting is to prevent the formation of matte, which is a lower sulphide than the original ore or artificially-formed sulphide. When once the roast-heap has become tolerably cool it is torn down, loaded on the cars by barrows, and transferred to the smelter, all of the ore which has not been thoroughly roasted being, of course, stripped off and kept for the next roasting. The average cost of roasting is estimated at eighty to eighty-five cents a ton.

## SMELTING.

By this is meant the fusion of the copper-bearing material with some one or more fluxes, when the copper, from its greater specific gravity, separates from the slag and is recovered. In the case of oxidized ores, it is obtained in the metallic condition somewhat adulterated with sulphur, iron, nickel, or whatever other metal may be present, but requiring only a single operation to bring it into the proper form for commerce. But when it occurs in combination with sulphur or arsenic, accompanied by an excess of foreign sulphides, the result of the first fusion is merely a concentrated ore freed from the earthy gangue and resulting from a combination of the copper with a sufficient quantity of sulphur to form a sub-sulphide ($Cu._2 S$), to which is added as much more sulphide of iron ($Fe. S$) as corresponds to the remaining sulphur. If tin, lead, or silver be present, they combine with sulphur for the most part and enter the alloy. The ultimate production being called matte, we consequently see that the grade of the matte will depend upon the amount of sulphur in the ore. There are two distinct methods of copper smelting, (1) smelting in Blast Furnaces, (2) smelting in Reverberating Furnaces. In this country and the United States the blast furnace has been generally adopted, the result being that it has been so improved and changed that the American system is far in advance of the European methods, being radically different from them. Such a revolution has taken place that whereas ten years ago the ordinary run of a furnace for twenty-four hours was forty tons, it now runs over 100 tons. I shall not here attempt to describe the Reverberating System, although the most of the copper manufactured still has at some stage to pass through such a furnace.

The great difference between the two methods is that a reverberating furnace will not smelt sulphides well, for the ore must be reduced to an oxide. The Blast System, however, will smelt any ore, and where the amount of sulphur is small it is not roasted at all, but at once turned into the furnace with its quota of flux and coke. The roasted ore is easily loaded on the cars, by which it is conveyed to the smelter, and here another tram is built, so that the ore is dumped into the second story of the building. The one end is divided into three spaces or large stalls, one for ore, one for coke, and one for fluxes.

### THE FLUXES.

If the ore contains much silica, little else will be required to form a flux; a small addition of clay being required. But since ores seldom carry enough fluxing, something must be added. Some of the fluxes used are silicious oxide ore, clay, slate, silica of alumina, pebbles, crushed quartz, sand, rock, etc., but by far the most important is lime. In some cases, where large furnaces are used, limestone is used, but generally the quicklime is preferred. The percentage of flux depends altogether upon the nature of the ore. The fuel used is either charcoal or coke. The three substances are mixed in an exact proportion, and in beginning work many trials are required to get the right proportion. The charging door is on the second floor, and each barrowful is weighed on a scale before dumping. A man is placed at this scale to note all weights and direct the proper proportions. The amount of coke used at Sudbury is 12½ per cent. All ore is weighed before going into the smelter, and then the matte is weighed and a sample of every day's work assayed, so that an exact account is kept and any loss of copper in the slag is at once detected. In speaking of blast furnaces we may omit a description of the small brick furnaces of that kind, but to trace the evolutions from such to the present plan is interesting, and at the same time would give perhaps one of the best lessons in smelting that could be obtained. It is not well settled to whom belongs the credit of having first adopted the principle of water-cooling to copper blast furnaces, but it was soon hailed as the greatest advance in the treatment of that metal that had been made for many years. By its employment the burning out and consequent freezing up of the furnace from the half-fused mass of molted fire-brick have become things of the past.

For a diagram showing some of the main features of the blast furnace, see Fig. 1.

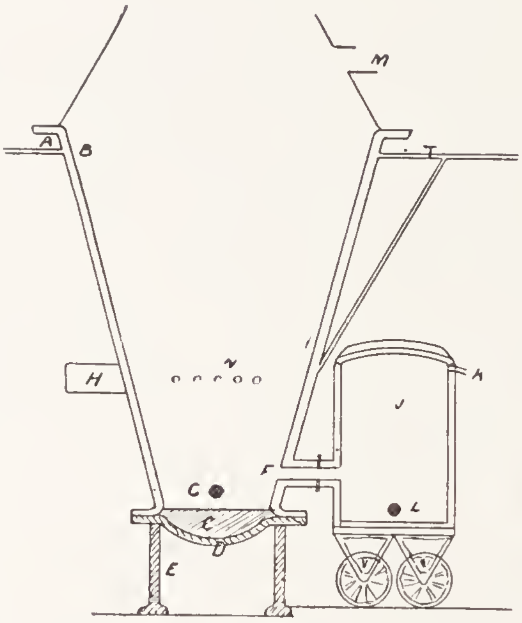


Fig. 1

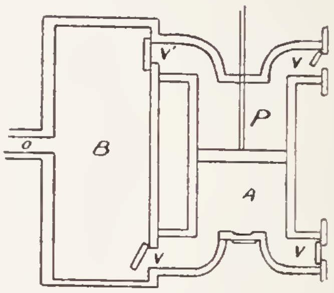


Fig 2

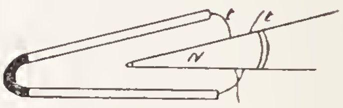


Fig 3

Here A represents the water-jacket made of the boiler-plate, the top is flanged two inches; B, the furnace proper, also of the same material, is flanged four inches, thus giving a water space of two inches; the flanges being riveted, and also having holes for bolting on the smoke stack. The bottom of the furnace, D, is a disk of cast-iron plate 2″ thick fastened to the bottom flange, to which are also attached the legs E. The hole F is the outlet of both slag and matte, and is 9″ high and 7″ wide, made by riveting the furnace and shell together at that point. The tap-hole G in the shaft is used only in blowing out the furnace; C is fire-clay rammed into the bottom on the supporting plate. H represents the wind-box; I the entrance of cooling water. J is the movable fore-hearth containing the crucible and placed on wheels, with fire-brick top and bottom and water space on the sides. K is the slag spout, and L the tap-hole for matte. M is the charging door where the fuel, ore, and flux is thrown in. The molten material flows directly from the shaft through the opening F into the crucible in J. The point between the two is readily made or severed, for it consists of two water-jacketed faces of iron, which are placed in contact by moving the fore-hearth against the opening. The two surfaces are smeared with fire-clay, which together with the molten matte immediately close up any small space between the faces. N represents the tuyeres carrying the blast to the furnace. There are from three to five on each side. The height of the furnace is ten to twelve feet, the width at top 4′ 6″ and 3′ 6″ at bottom. The water-jacket was formerly made about four inches wide, but of late has been much reduced. The cold water is introduced near the middle or lower part of the jacket, and on account of its weight sinks to the bottom, where becoming warm it rises to the top and passes out. In a thirty-six inch furnace the water necessary (when used over and over again) amounts to only 3,000 gallons a day. Frequently this water is used for the engine running the fans. The tuyere pipes, by which the blast is conducted to the furnace, are from two to four inches in diameter. They pass through the water-jacket and extend eight to ten inches into the furnace at about 6″ to 8″ from the bottom. Sometimes they are water-jacketed but more frequently are just cast-iron nozzles. To prevent the blast from reaching the outside crucible, it is arranged to have the slag-lip about 12″ to 18″ above the outlet from the furnace; thus when the molten metal runs from the furnace to the crucible, the level is soon raised above the opening and will continue to rise until the slag-lip is reached, the matte and slag standing at the same level in both crucible and furnace, and thus the blast is effectually cut off from the crucible. This state may be maintained provided the crucible is not, when tapped, emptied of all its contents; if such should occur a blast of cinders, slag and matte at once appears at the tap-hole. The blast supplied is from a Baker blower, No. 4½, which at 115 revolutions per minute will supply ten ounces per square inch of blast. This may appear a small blast, but when it is understood that the heat obtained is only to fuse the ore, not to reduce it, it will readily be seen that a stronger blast is not necessary.

Two different systems of blowers have been used:

I. Those producing a positive blast, and which, if obstructed, must result in the bursting of some part of the apparatus or the stopping of the blower.

II. Centrifugal fan-blowers which, even if obstructed, continue revolving. They consume much less power, the air being simply beaten by the vanes but not passing out of the pipe.

One advantage of the first kind lies in the fact that sometimes the matte becomes cooled on the tuyere pipes, forming what are called noses, which will continue to grow until the opening is closed, unless a strong blast be produced to keep it open.

Figure 2 shows the principle of the first kind of blower.

Here A is a large cast-iron cylinder accurately turned on the inside, in which the piston P works up and down, and made air-tight at the piston opening. The cylinder is closed at both ends by carefully-fitted iron plates. The cover is provided with two lateral openings V and V′, one of which V communicates with the outside air and is furnished with a valve opening inwards; the other V′, on the contrary, opens outwards and communicates with another chamber, B, also of cast-iron. The lower end of the cylinder is constructed exactly like the top.

To understand the action of this machine, let us suppose the piston has been raised to the full extent and has begun to be again forced down. If the valves V and V′ of the upper chamber are closed, the air contained in the upper portion will gradually become more and more rarified, and the difference of density of the air inside and out will cause the valve V′ to apply itself firmly against the metallic bearing before which it is hung. The valve V, on the contrary, which opens inwards, will be lifted and air will pour into the chamber from the outside. The motion which causes the air above the piston to dilate will evidently at the same time compress that which is beneath, causing the valve V to close, the valve V′ to open, and forcing the contained air to the chamber B, from whence it escapes through the aperture O to the pipes connecting with the tuyeres. In this way the upper portion of the cylinder draws the air from without during the descent of the piston and forces that which is beneath into the pipes with which it connects, and when the piston is raised these operations are reversed in the upper and lower chambers. Thus there will be an almost continuous blast supplied to the tuyeres; the only time when any irregularity will be shown is when the piston is at the end of the stroke; but to prevent the check thereby caused, the pipe leading from the chamber B is made to connect with a large closed reservoir, where the variations referred to is lost through the elasticity of the air itself. The cylinder is about six feet in diameter and nine feet long, while the piston makes about thirteen strokes a minute, furnishing about 12,000 cubic feet of air per minute to be discharged through the tuyere area.

Fig. 3 is a diagram of a water-jacketed tuyere showing a vertical section through it. It consists of a conical tube of cast-iron, in which an annular space is preserved in the metal composing the sides. Through this opening a current of cold water is made to circulate by means of two tubes t and t′, one of which t supplies the cold water, while the other t′ carries off that which has become hot. In this is placed the nozzle N, made either of thin copper or sheet-iron, and connected with a leather hose or otherwise with the pipes leading from the the blower. The pipes are set pointing slightly downwards, so as to prevent one tuyere blowing into another.

Now to follow the ore through the process, starting from the weighing and mixing. The ore, flux, and fuel are cast into the furnace from iron barrows, which are wheeled up alongside of the charging door and dumped. As the mass settles down it becomes heated up, and then the mixed fuel, at the tuyeres, creates a powerful heat, by which the ore and flux is melted, and the slag being taken up by the flux, the whole sinks to the bottom and runs out into the crucible, where the matte and slag separate, the slag floating and the molten metal sinking to the bottom. When the level reaches the slag-lip, which is always open, the slag flows out and into a slag buggy placed to catch it. After a time the metal will begin to show itself at this opening, and is indicated by a greater fluidity and much spluttering. Then a slag-buggy is wheeled up to the side of the crucible, which is then tapped. The hole, which is stopped with fire-clay, is opened by driving a pointed iron rod into it, which breaks the clay. The rod for this purpose is of ⅜″ iron and 10″ to 12″ long, and upon tapping there will be a sudden spurt of matte to the distance of four or five feet. When sufficient has been drawn off, the opening is stopped with a ball of fire clay made on the point of another rod of the same length and pressed firmly into the tap-hole. The tapping is done at regular intervals, the object being never to let the matte overflow at the slag-lip ; care also being taken never to lower the level of the crucible so much that the slag will flow out at the tap-hole. The floor of the smelting house is covered with iron plates, so as to prevent burning when the matte or slag falls upon it. The slag is wheeled out and dumped and from its bulk soon increases to a considerable size, so that much care is required to so arrange the dump that as little labor will be required as possible in its disposal. The matte, after running into the matte-buggy, is wheeled out and allowed to cool, when it is dumped and afterwards broken by sledge, ready to be loaded on the cars for transportation. The slag-buggies are merely large pots about 18″ in diameter and two feet deep, which are hung on two wheels, to which is attached a handle for drawing. The pots are larger at the mouth than at the bottom and are made of cast-iron ½″ thick.

The capacity of a blast-furnace is dependent on many varying causes and is to a considerable extent independent of shape or size, though its tuyere area is, of course, the most important function in determining the amount to be smelted. Next to the fusibility of the charge, the pressure and volume of the blast have the principal influence in this determination, provided the fuel is the same and of sufficient density to stand the pressure of the blast. Both ore and fuel are spread in layers over the whole area of the furnace, which procedure is quite different from the old plan.

Large and high furnaces naturally require heavier charges, and it is still an unsettled point as to whether deep or thin layers of fuel and ore serve the best purpose, while some claim that they should be to a certain extent mixed. A proper charge for a 36″ furnace is 500 to 800, while a 42″ will take 1,200.

In Canada we have not as yet carried our copper smelting any farther than the production of rich mattes, but these are all shipped either to New Jersey or Swansea, to be there refined. This refining is done chiefly by the reverberatory furnace. Underlying the whole process is the fact that copper has a greater affinity for sulphur than for oxygen, while the other metals generally present in the matte have a stronger affinity for oxygen than for sulphur, and thus we can understand how it is that metallic copper is never obtained at the first or second treatment, since the sulphur is used as a means of concentrating the copper, while at the same time the impurities are to be got rid of. The matte is broken up and placed in the reverberatory furnace together with silicious fluxes. The iron and other impurities in the form of sulphides become reduced to sulphates, then to oxides, and are carried off into fluxes. This process is repeated several times until an almost pure sub-sulphide of copper is obtained, which will also contain any metallic copper which has been reduced in any of the processes. This last form is called white metal, which is next smelted with a small amount of coke or coal and thoroughly roasted to an oxide, which is afterwards roasted with a fresh supply of coal, when the carbon combines with the oxygen and sets free the metallic copper in the form called blister copper. This is treated by hammering and rolling to bring it into a marketable form.

It has been the object of this paper to treat only of the reduction of the ores to the form of mattes, so that this last sketch is only given to show in a very few words the treatment after it leaves our Canadian smelters. With the activity shown during the last ten years, together with the prospects of the future, it is to be hoped that our vast mineral resources will justify the putting up of smelters for the perfect treatment of copper ores in our own country. Our one great drawback is, of course, the lack of coal, but if the mining companies can succeed in getting the duty on that article removed, doubtless we will soon have a perfect smelting process, and then we have every reason for believing that Canada will become the chief source of the supply of copper for the world.

No. 5 1891-2

# ⋈ PAPERS ⋈

READ BEFORE THE

# ENGINEERING SOCIETY

OF THE

# SCHOOL OF PRACTICAL SCIENCE

## TORONTO

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# PREFACE.

In the Spring of 1885, through the efforts of Messrs. Herbert Bowman and T. Kennard Thomson, assisted by Professor Galbraith, was laid the foundation of the Engineering Society of the School of Practical Science. With Professor Galbraith as first president, succeeded in turn by students, the Society has had a very satisfactory progress and growth, the evidence of which may be seen by comparing memberships of the present and inaugural years. Beginning with a few members it has increased to over 200. Meetings are held on the second and fourth Tuesdays of the academical year, at which papers and questions of engineering interest and importance are read and discussed. The programmes are varied at times with discussions of questions not relevant to the papers read, which offer opportunities to each member to benefit himself and the Society by giving the results of his experiences and individual research in matters of engineering interest.

While at the same time giving every possible attention to the interests of the undergraduates, those of the graduates are not lost sight of. To this end papers read during the previous session are published each year and distributed.

The papers in the present edition have been contributed chiefly by students, and have been carefully selected; those bearing the mark of originality and personal research being published. Though at first sight this seems like putting an embargo on the efforts of the student, who during the session has his time pretty fully occupied with the work of the course and can ill afford the time for the preparation of a paper otherwise than by compilation, it is thought that though the paper may be short it is worth more to the Society than a lengthy and compiled one, provided it be original and supply ample food for discussion. This latter characteristic fixes the standard of excellence on which is based the selection.

Special attention is called to the papers of Messrs. C. Marani and J. A. Duff, B.A., graduates, which when read elicited lively discussion.

The general committee hopes that graduates, now engaged in active work, will add their quota to the interest of the meetings by contributing papers closely bearing on their work, which to the student proves a great source of interest by providing a means of comparison between the practical and the theoretical.

The present edition consists of 1000 copies, which will have a wide circulation among engineers and surveyors. Exchanges are also made with other Associations, whereby the distribution is extended.

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# ENGINEERING SOCIETY

OF

# The School of Practical Science

TORONTO.

## PRESIDENT'S ADDRESS.

*Gentlemen,*—It is my first and sad duty to-day to refer to the loss, we as a Society have sustained, through the death of our late past president, Mr. J. K. Robinson. Those of you who knew him personally can well understand my inability to pass a eulogy worthy of so high and noble a character. He was endeared to us by many ties, fraternal and social. As leader of our executive he was energetic, zealous in promoting the best interests of our Society, upholding with honor and dignity the high position you had conferred upon him, which he so well merited and so ably filled. As a student, assiduous, as a friend uniformly kind, gentle and unassuming. His religion was decided, but never obtrusive nor made obnoxious to his fellow students. His acts were the outcome of principles founded on a true conception and a high ideal of right. He was a man in the highest sense, and as a man, he has left us the richest of all legacies, an example of true manhood, industry, and truth.

It is my privilege to thank you for the position I occupy to-day, the highest in your power as students to confer on one of your number, and although I cannot adequately express my feelings, this inability does not in any degree lessen my gratitude to you for this expression of your confidence.

I would confess to a feeling of self-deficiency to do full justice to the position, were it not for the fact that you have elected to assist me a committee, whose sound judgment in matters deliberative can be fully relied on. Beside this, I feel full confidence that each one of you recognizes his individual responsibility in matters pertaining to the Society, and that you each have come with a full determination to do all in your power to make the session on which we are entering one of the most successful and progressive in the history of the Society. I cannot hope to reach the high plane of executive ability in which our Haultain, our Duff, and our now lamented Robinson moved, but I anticipate that that my lack in this respect will be more than compensated for by your own extra endeavors, and I will do my utmost to interpret your wishes as a Society, and to prevent the occurrence of anything that would cause you to regret your action in placing me in the position you have.

On behalf of the Society I welcome those of you who are here for the first time to-day, and who, although not as yet formally members, show by your presence here the desire to take part in student associations and Society work, and who, therefore, we consider virtually members, and co-workers in fulfilling the objects for which our Society was formed.

There is sometimes a tendency on the part of young students to deprecate, or at any rate to not fully appreciate the advantages and benefits to be derived from a regular attendance on the meetings of our Society. This is in every case the fault of the individual. If you come here expecting to be entertained by a comic concert, or musical recital, you will, I admit, be disappointed. But if you come to learn, to improve your mind, to increase your store of knowledge, you will be more than satisfied with the opportunities afforded you. Our meetings are always instructive, always entertaining to those who come to the School with their minds made up to excel in the profession they have chosen, and thus be worthy students of a grand institution. In the discussion of papers read before the Society, in the consideration of business in connection with the Society, you will be expected to take part. To point out errors, to suggest improvements, and to give your reasons for each in an intelligible and concise manner, will be your duty as well as your privilege, as a member of our Society. This is an important and useful accomplishment for any one, but it is particularly important and useful to engineers who have to deal with municipalities and corporations, the individuals of which, as a rule, are none too well supplied with mathematical perception.

But there are other and just as valuable advantages to be gained as those pointed out. I refer to the opportunities that a society of this kind offers for the study of human nature as exhibited in your fellow-students, and thereby a comparative and beneficial study of yourself. In our debates and discussions there will be differences of opinion, cross-firing of words, the faults and virtues of the one individual will be brought in contact with the opposite qualities of the other. In the collision there will be a dissipation of the excess of each, or rather, perhaps a harmonious blending of opposites; each will come out of the fray a more fully developed, a more symmetrically formed character, better able to cope with the opposition that we will each receive when we leave college and enter upon the stern conflict of life.

Then there are the privileges in connection with the Engineering Society Library. There you find all the latest literature referring to engineering and architectural subjects and work, books of reference, models, plans of work; you have the opportunity of getting your drawing paper at cost price from the librarian, as well as having a cosy and comfortable place to put in a spare half-hour in storing your mind with useful knowledge.

I would like to impress upon you at the beginning the importance of weighing well every question that is brought before you as members of our Society for consideration. Every motion that is brought up for discussion is going to have in its acceptance or rejection, an effect either progressive or obstructive to our Society. How necessary it is then that you should each give it your calm and careful deliberation before either sanctioning or opposing it by your vote.

There is sometimes a tendency in this, as in other societies, to rush a motion through, before its full meaning has dawned upon the majority of the members; some vote mechanically, some vote through the influence of others who they think ought to know, some conscientiously refrain from voting at all. Let your actions through the coming session be such that none of these imputations can be brought against you. Be honest in your consideration of the questions, independent in your decision, and use your franchise accordingly. In this way you will be best fulfilling your duty to the Society.

It may not be out of place to say a few words here in connection with the advance our School is making, and the corresponding progress of our Society. The last year has been a red letter one in the history of the institution, whose progress has been marked by many great improvements during the past few years. To attempt to give an historical account of how the School of Science has risen to the proud eminence upon which it now stands would be out of place here, and to show how the Engineering Society has at the same time attained its present standing, is equally laborious. But certain it is, the Engineering Society has become an organization worthy of its connection with our School and of the ambitious aim to which it strives, and such an organization as every loyal son of his *alma mater* should be proud of.

Our Society has grown in influence during the past year, and if there were no other proof of the fact than the increased attendance which was shown, such would be sufficient; but besides this we have a more important proof: that is, the increased interest which was manifested in the Society's affairs and proceedings. From the first speech of welcome last October, until the last echoes of the soul-stirring "Auld Lang Syne," which we sang here at twelve o'clock on the night of 28th March, had died away, the spirit of interest was unfailing, and as now we enter upon another bright and propitious cycle, we exhort again an increased manifestation in you of that spirit of loyalty and interest which has made this Society what it is.

Financially, we have been prosperous, and this year we enter upon our work with a balance sheet showing a pleasing surplus to the Society's credit.

Our pamphlet too demands a word of mention. Many times have we heard both at home and abroad of our last year's publication being admired for its excellence, by professional men, both practical and theoretical, and such we must consider as no slight compliment to its value, especially to us as students. While passing it may be well to remark that our new members cannot overestimate the advantages to be derived from a careful perusal of its pages; it is an easy thing to cast it aside as having no interest for you, but you will find it not such an easy thing to pick up the gems of research and knowledge which it contains and which you have unwittingly flung away.

Especially marked during the past year is the manner in which the high reputation of this Society has become spread abroad. Members of our circle are engaged throughout the whole continent, numbers of these keep up a constant communication with us, thus showing how highly they value the connection. But chiefly in our own city do we find the influence of the Society felt. It is now recognized as an actual professional institution, and last year it was no uncommon occurrence to be honored with the presence of prominent engineers at our Society meetings. In this connection we might make mention of the valuable paper read and service rendered by Dr. Bryce of the Provincial Board of Health.

Since last year there have been two important changes in the curriculum of the School: the addition of a Fourth Year to the course and the establishment of a lectureship in Sanitary Engineering. The courses as they stood before were without doubt most thorough in their training, and we welcome the extra year to our work as a valuable addition which will make our course in each department at once most thorough and practical. This extra year will be indirectly a benefit to the Engineering Society. It will promote original and individual research, the encouragement of which is one of the objects of the Society ; it will bring an element of more advanced thought and experience into the meetings of the Society, besides being the means of contributing a greater number of active members to the Society. The value of this Fourth Year can scarcely yet be estimated, and we hope the time is not far distant when it will be made a compulsory year of the graduate course.

In reference to the lectureship in Sanitary Engineering. This appointment will, we feel, supply a long felt want in the School ; for the wants of the age demand a more scientific and thorough treatment of this branch of engineering. Mr. C. J. Marani, who is appointed to fill the position, has made a special study of Sanitation from both theoretical and practical standpoints ; and his being a graduate of the School gives us every reason to believe that this department will not fall below the high standard required by the proud position our School occupies among institutions of its kind.

We are pleased to welcome back to our midst as Fellow in Engineering, Mr. J. A. Duff, B.A., a graduate of Toronto University, and also of the School of Science, who has been away extending his knowledge in the more practical side of engineering, and who has now returned to give the students here the advantage of his increased experience.

Mr. Duff is one of the old war-horses of our Society, having filled the position of President in his final year. He always took an active part in everything connected with student life, and his assistance, which we anticipate will be freely given, will be of the greatest value to the Society by reason of his large experience in executive work.

Before taking my seat I would like to say a few words on a subject which you may consider irrelevant to my position. If so, I would justify myself by the statement that I consider, "Whatever is of interest to the students of the School as a whole, should be of interest to us as a Society," for "Student of the School of Practical Science" and "Member of the Engineering Society" should be synonymous terms.

To-day there is one of our number upholding the standing of Canadian athletes across the Atlantic. We contribute our quota to the support of the baseball, the lacrosse, and the football played on the college campus. We are proud of the part we take and the standing we hold in general college athletics. But we are a distinct institution and we should have a distinct athletic relation. This may appear impracticable at present, on account of the very limited time we are allowed in the curriculum for such recreation. But if we make up our minds to a systematic way in using our present opportunities, and do our best to foster an independent athletic spirit, the developments resulting, I have no doubt, would be far more encouraging than we even expect. Do not think by my emphasizing this I would wish you to sacrifice the more serious work for which we come here. On the contrary it is for the purpose of making more effective the time we spend over our books and drawing boards, that I advocate the cultivation of this spirit, so that we may enjoy to the fullest extent the motto of our School,

"SCITE ET STRENUE."

R. W. THOMSON.

# SANITARY PLUMBING.

### By Cesare J. Marani, Grad. S.P.S.

*Mr. President and Gentlemen*,—Having been requested to read a short paper before you, and, having had occasion to come into contact lately with architects and plumbers in connection with sanitary matters, pertaining more especially to the proper construction and disposition of the plumbing work in dwellings, it occurred to me that I might bring the subject of sanitary plumbing before the Society, and express my views.

But before doing so, permit me to say that the subject of "House Plumbing" has grown enormously within the last few years, and that now it holds a place of no small importance in the planning of buildings. For this reason it is impossible for me to do otherwise than to touch on such points as I consider of greater importance, and which, I fear, are often overlooked by the owner and architect.

Now that an increased desire for thorough sanitation is being manifested by the better classes, the sanitary engineer is often called upon, if not actually to take charge of the plumbing work, at least to plan and advise in the interests of health and economy.

At present this work is largely controlled by the architect and plumber combined, who seem more eager to attain to better results, and much more competent to do so, than they were formerly. Still it cannot be denied that the average architect possesses little or no scientific knowledge whatever on this important subject. Thus clearly demonstrating a fact, that he and the rest of his profession attach too little importance to their responsibilities in connection with the plumbing of buildings, and therefore do not seem to experience for this, that feeling of personal accountability so essential to success, which they do for other and less important sections of their work.

It is hardly necessary to explain that in these, and the remarks I am about to make, I refer not to the average members of "associations of architects," such as we now have in the Provinces of Ontario and Quebec, nor to the Boston Architectural Club, and other Societies in the States; but to the *average*, when we include all who may be said to be practicing as architects, whether considered qualified to do so by these architectural bodies or not, and therefore, in this way considering the *actual* centre of gravity that affects the general public.

Col. George E. Waring, in writing on this subject for the information of architects, as well as others, goes on to say: "I have never applied a water test, under pressure, to work that has been done in a fine house under control of an architect, with any other result, so far as his frame of mind was concerned, than to annoy him by the demonstration of leaks and defects.

"What seems still more remarkable, when I have sometimes thought that I had an architect really converted, when he acknowledged the work to be simple, elegant, safe, cheap, and in every way satisfactory, was that the conversion never lasted. I never found that the example had the slightest influence on him afterwards."

Sometimes we meet with owners, who, while they show all eagerness to consider from a standpoint of comfort, any proposed piece of plumbing work in connection with their house, nevertheless seem afraid to look on the sanitary aspect of the thing; lest the necessity of adopting certain changes or precautionary measures, might rise perforce before them, like the unwelcome ghost of Banquo. In the first place, any additional expense thus entailed, proving little or no obstacle; while in the second, the smallest outlay for the protection of health, would be regarded as a *dead loss*, and objected to in every possible way.

That an architect should ever pander to the wishes of such people, who may be said to be pursuing an Ostrich-like policy, is indeed to be regretted.

Sometimes an owner imagines that his rights as Despot in his own Castle are being encroached upon. It is then the duty of the architect to point out the wisdom of providing for the preservation of health and happiness, not only of himself, but also of others, since we are creatures very much dependent on our neighbors for our sanitary condition.

I knew an architect once, who tried to exonerate himself from all responsibility in connection with a certain piece of "plumbing work," by saying that he had persuaded the owner to employ the best *practical plumbers* in town to do the said work, and that therefore there could be nothing wrong with it.

Obviously the above reasoning was rather sophistical. Who constitute the "best practical plumbers" in a community? Are they men of science as well as clever mechanics? Are they fully entitled, by a sound experience and careful study of their trade, to the full import of such an appellation? I fear not, and certainly much less to that signification which a too confiding public is ever sure to place on such titles. It is a fallacy to imagine that the knowledge of how to handle, cut, and connect pipes, wipe joints, and charge well, of necessity make a man master of the plumber's trade. And yet I know from experience, that in the great majority of cases, this is regarded as the criterion. It might seem that the impression prevails among a large class of pipe fitters and mechanics, that the possession of a certain number of working tools, together with the *valuable* assistance of a couple of incompetent "shop-boys," a large shingle suspended over the sidewalk, more pronounced in its economy for truth than expense, a few cast iron connections displayed just outside the shop, and lots of gas brackets and other brass fixtures inside, constitutes a man at once a "practical plumber." There are a great many good workmen who are by no means good plumbers, and still a greater number of good plumbers, who are by no means "Practical Plumbers and Sanitary Engineers," as they often style themselves.

It therefore falls back on the architect to provide the soul, yes, the ethereal spirit of theoretical knowledge, and furthermore, to see the same properly and practically incorporated in the work of the plumber. That a man can pursue the plumbing trade without having first thoroughly mastered it in all its details, I consider as the great present evil. Hundreds of dollars have been spent, to my knowledge, in rectifying blunders made by such workmen, of whom it might be said, and this justly, that they had come by their trade dishonestly, because by too short a route. They, of course, little cared what might befall to their work, much less to the health and happiness of others, so long as they might pocket their gains and remain in blissful oblivion as to their moral responsibilities. As an illustration, of what I should term downright practical ignorance, I might give a case that occurred in the town of Brockville, Ont., a few years ago.

One of the so-called "master plumbers," who, previous to his settlement in the town, had worked at his trade for nearly fifteen years in the city of Montreal, and who was therefore looked upon by the simple public as a most desirable man to employ, actually presented a piece of "plumbing work" to be passed and approved of by the Inspector, where a two inch lead pipe, two feet four inches in length, had been bent and used under the closet seat, so as to act as a vent pipe to the closet trap, and at the same time as an overflow waste for the bath tub (see fig. 1). The workmanship, however, was simply perfect.

Not very long ago a case came under my notice in this city, where a long vertical line of soil pipes had choked and blocked up completely. It was thought at first that the servants must have thrown bones and rags, etc., down the closets, but further examination showed that there was nothing in the pipes, save the legitimate house wastes and closet paper.

The plumbers, in erecting the said line of pipes, had used too little gasket in some of the joints, and none at all in others. The consequence was, that the lead intended for the joints had spurted inside, and in some cases forming regular groups of fingers across the pipes, thus obstructing the passage of paper, etc. The only way this could be rectified was by the tearing down and re-constructing of that vertical line of soil pipes.

On investigation, it was found that the plumber, who was responsible for this, had had no intentions of scamping his work. He had made some extraordinary experiments (by himself), which had convinced him against using a gasket where he could possibly help it. He had come to the conclusion that though a gasket was of great assistance in preventing any loss of lead while pouring a joint, yet from a sanitary standpoint it was objectionable as absorbing and retaining filthy liquids. In the interests of his employers therefore, he had decided to use gasketing only where it was impossible to do without it, and the good faith of the man was manifested in that he had not charged for gasketing, nor for the amount of extra lead he must have lost in trying to fill the joints. It is needless to explain further.

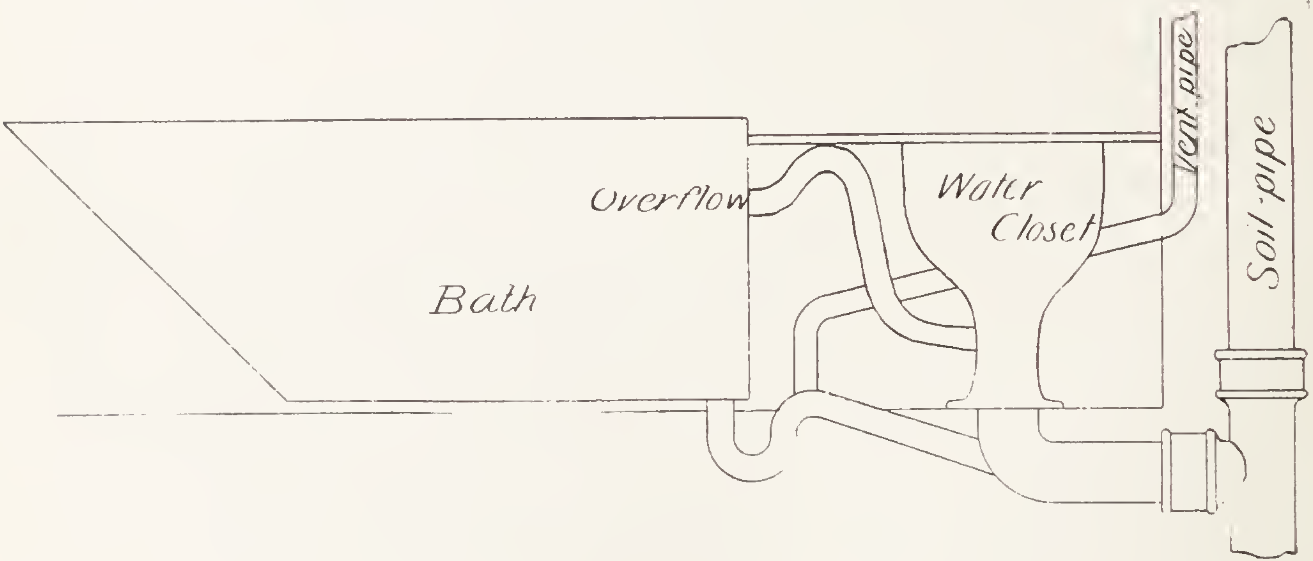


FIG. I.

To my mind the house is the unit of sanitary administration. In fact, the whole sewerage system beyond, with its many intricacies and problems, both mechanical and financial, never would have developed, nor even have sprung into existence, but for the dwelling.

We may look upon man's modern habitation, therefore, as the principal source from whence all sewage emanates.

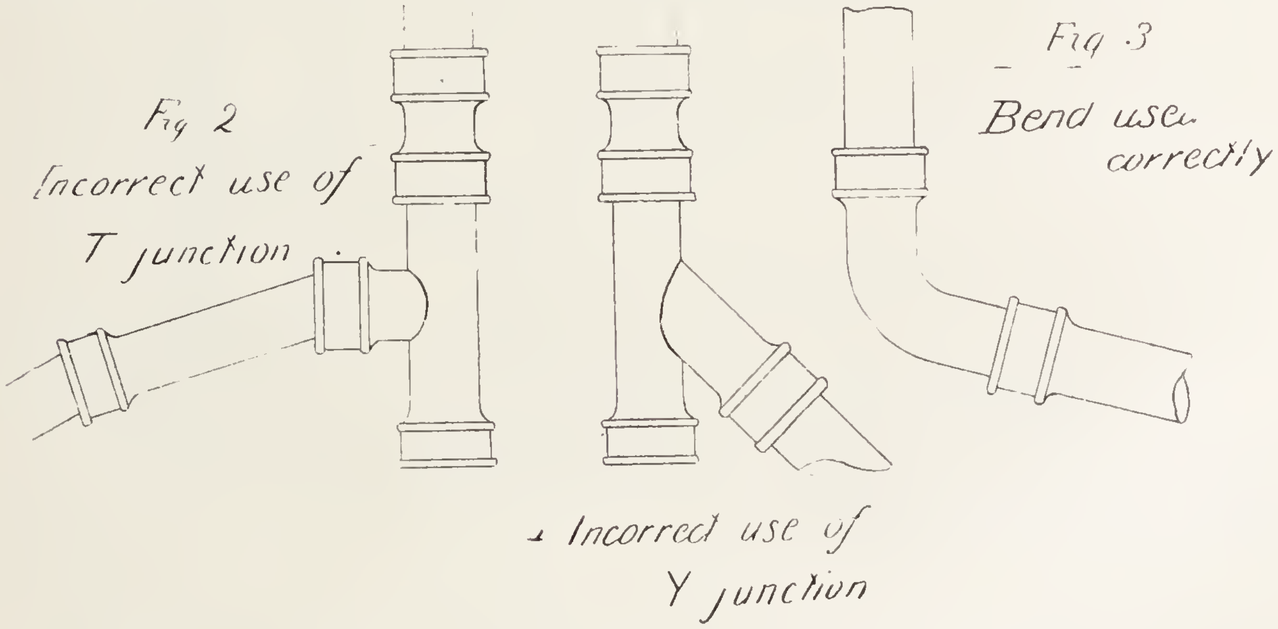
To secure perfect safety to the inmates, while removing at the same time the daily household wastes beyond the outer walls, is then our first consideration.

Except where houses are isolated, or strung out in small colonies along concession roads, or again clustered into hamlets or small villages, what is known as the water carriage system, is by far the most efficacious for the removal of the daily semi-liquid and liquid wastes of the dwelling. By wastes, I mean human excreta, chamber slops, water used for baths, water in which dishes, pots, vegetables, clothes, etc., have been washed, and in fact any water that has been put to a thousand and one of its other uses in a house. We might consider the following as our "plumbing" axioms, and the system with its fixtures, traps, ventilation, and waste pipes, etc., that will conform in the highest degree to them, must perforce be accepted as the best. It is then evident :

Firstly.—That the waste matters generated in the house should be removed at once.

Secondly.—That in so far as it lies in our power, the waste pipe system should be freed from any tendency to retain decomposing matter giving off gaseous products known to be detrimental to health, or these very gases when generated elsewhere.

Thirdly.—That every part of the plumbing should be visible where possible, and conveniently situated as against repairs or accidents.



Fourthly.—That all parts should be of sound materials free from flaws, blemishes, or other defects, and of the kind of material best suited for their special purposes.

Fifthly.—That the whole system should be put tightly together, in the best approved manner, and possessing uniformity in strength and durability.

Sixthly.—That the whole system should be as simple as possible, consistent with convenience, efficiency, and security.

Seventhly.—That the appliances used should be economical, reliable, and adding materially to the comforts of the inmates of the building.

*That the waste matters generated in the house be removed at once*, can be attained by having as direct and short a line of waste and soil pipes as possible. Every necessary bend in a line of pipes being made by a regular curve, and never abruptly. Wherever the waste and soil pipes run otherwise than vertically, ample grades should be provided. The smoothness and evenness of the interior of the pipes, along with their size, and also the manner in which they are connected and branched together, having a marked effect on the velocity of discharge.

The use of an inverted **T** or **Y** junction for the purpose of effecting a connection between a vertical and horizontal line of pipes, should never be tolerated. The reasons are obvious (see figs. 2, 3). I have actually come across several cases of this unscientific mode of construction.

As there seems to exist, even among writers on sanitation, an uncertainty as to the exact meaning of the terms *house drains*, *soil pipes*, *waste pipes*, etc., it might not be out of place for us to decide upon their proper application before proceeding further. Let a house be given us, and a hundred feet away the street sewer. (See fig. 4.)

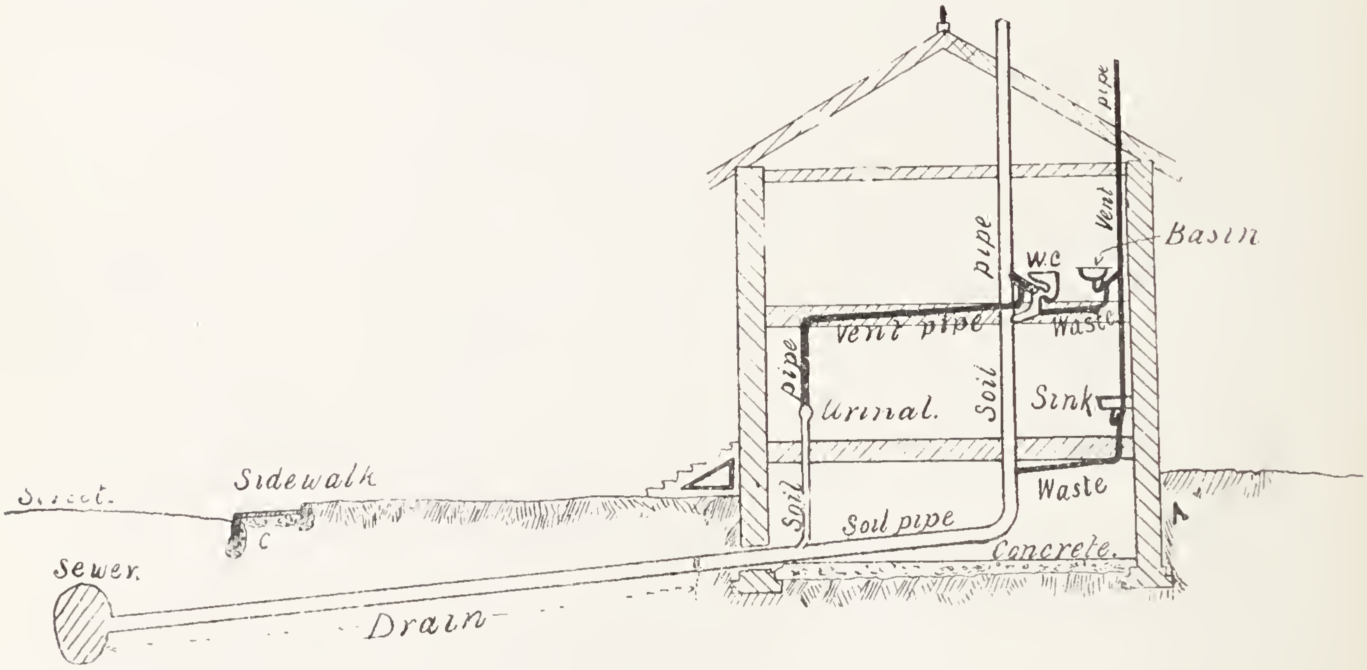


FIG. 4.

Then the system of pipes commencing at the street sewer, running up to the walls of the house, passing through them, and then branching out throughout the building, may be divided into two parts. First, that part outside between the street sewer and the outer walls ; and secondly, that part inside the dwelling. The first is known as the *house drain*, or *drain*, and conveys to the said street sewer all liquid and semi-liquid wastes, and further, all roof and cellar water that may be trapped into it.

The second part, inside the dwelling, is again sub-divided into *soil pipes*, *waste pipes*, and *vent pipes*.

Soil pipes, or soil pipes, are those pipes that carry away human excreta, principally from water-closets, and form the main trunks of the plumbing system of buildings. As such, therefore, they almost invariably receive in addition, the wastes from baths, basins, sinks, tubs, etc., that are conveyed to them by the waste pipes of the system.

Laterals to the main trunks, receiving liquid excreta from hoppers and urinals, are called soil pipes only in a secondary sense, while vent pipes form that part of the system, which does not convey waste waters or sewage of any kind, but is intended to afford free ventilation to the different parts, and to prevent the syphoning of traps. Such portion of the soil pipe as may be found above the highest fixtures, however, and there for no other purpose than that of ventilation, curiously enough retains the name of soil pipe, and does not come under the classification of vent pipes.

We therefore have waste pipes in connection with all fixtures, save those into which human excreta may be emptied. These waste pipes may either enter the house drain independently, or join the soil pipe and discharge their liquid wastes into it.

Soil pipes again may convey excreta alone, or all the wastes of the house to the drain beyond the walls, while at the same time acting as the main ventilating shafts of the system, since their upper ends are always left open and carried well above the roof.

Lastly, the house drain, or simply drain, conveys to the sewer all liquid and semi-liquid wastes placed beyond the walls of the building by the soil and waste pipes.

It must be understood that we have simply considered these terms as applied to house plumbing, and house drains, and not as in the subject of land drainage, nor as in certain of the distinctions used in what is known as the "Separate System of Sewerage."

*That in so far as it lies within our power, the waste pipe system be freed from any tendency to retain decomposing matter, giving off gaseous products known to be detrimental to health, or these very gases when generated elsewhere.*

From the mechanical side I should say, have the work done by a thoroughly reliable and competent workman, one who knows and realizes the importance of honest workmanship in connecting pipes, in ventilating traps, etc. To place the work in the hands of an admittedly good man, a thorough mechanic in himself, but one who always employs undermen to do his "jobs," and then to rest at ease with the false idea that your share of the work has been performed, and that the workmanship will turn out as desired, reminds me of the story of that simple-minded housewife, who, after placing her marketing of game and fowl on the table of her cottage, and then firmly securing the windows as against the ingress of eagles and other birds of prey, went off leaving the cottage door wide open. During her absence, the fable goes on to say, bears, and other beasts, entered and carried the marketing away.

It is the duty of the architect to determine whether the men actually doing the work are competent or not; and further, he should insist that the work be done by competent men, and competent men only, otherwise all kinds of defects will crawl into the system and prove beyond detection when the work is finished.

Recesses due to badly constructed joints, beads, and strings of solder, or the ends of gaskets in the pipes, all tend to retain filth. Bad connections between vent pipes and traps, destroy the efficiency of the latter. Unnecessary traps, or want of sufficient grade, are again, blunders for which the architect or designer of the plumbing system is alone to blame.

The sizes of the soil pipe and waste branches have also an important bearing on this point. For unless they are so proportioned as to be self-cleansing, the interior surface of the whole system will coat over with a greasy slime, known to give off pestiferous gases ten times more abominable than those found in the main sewer.

Ventilation, while indispensable as a diluter and safe remover of any gases forming or collecting in the system, tends furthermore to arrest, and to a great extent destroy, such a coating. The free ventilation of the whole system, therefore, demands our most careful consideration. This brings up a point still at issue among leading sanitary authorities:—"The whether a trap should be placed on the house drain before it empties into the street sewer, or not." I am inclined to side with those who hold that, while there may be some doubt as to the policy of omitting such a trap in cities, for instance like Toronto, where in the first place the main sewers have been ill constructed, and still more badly ventilated; that, even in the case of only tolerably good sewers, such arguments are only valid that advocate the omission of such traps. It is a fact that such traps arrest the flow of the waste liquids along the pipes, and therefore destroy in a measure their scouring properties, besides reducing the efficiency of carriage of the said liquids.

They also tend to complicate the system by rendering it necessary to introduce a fresh-air inlet pipe, on the house side of their water seals, in order to provide for ventilation.

At the best, this additional pipe, when brought a few feet above the ground, certainly does not add to the artistic effect of a building, and may sometimes prove dangerous to children who may be playing in its vicinity. For since we have the pressure of this obstructing trap on the one side, and sometimes a descending column of water in the soil pipe on the other, any gases thus confined between the two, can only escape by this so called "fresh-air inlet pipe."

Besides, I feel fully convinced that the best and most uniform ventilation for our line of pipes and drains can only be secured when we open one end into the larger street sewer beneath the ground, and the other towards the starry firmament above the roof.

*That every part of the plumbing be visible, wherever possible, and conveniently situated as against accidents and repairs.*

It is not so long ago since you could not find a single fixture in even the most costly of dwellings, that was not tightly cased in wood. This was particularly so with the water closet. Sanitarians pointed out the dangers to health arising from such a practice. and to-day one can judge of the general improved tone of public opinion on the matter, by just simply looking through any of the numerous descriptive catalogues issued by manufacturers of plumbing fixtures, etc., who, of course, study the demands of the market.

The public taste is certainly tending in the right direction, when marble-topped wash basins, supported merely by open brackets or brass legs, and water closets free from all woodwork save for an oak or mahogany top, are being introduced into the better class of dwellings.

Still we find that certain parts of our system, just as important to the efficient working of the whole, but because of less pretentious appearance than the wash basin and water closet, often seem to have been sadly neglected in the apportionment of the plumbing expenditures. I refer to the all important kitchen *sink*, and servants' hopper.

One often finds that while care and judgment are manifest in the selection and arrangement of the other fixtures of a house, any cheap concern has been accepted to pass for the kitchen sink. But, as if instigated by some secret feeling of doubt as to the justifiableness of such a course, and as if ashamed of the uncanny result, we find that the owner, or architect, has had it securely encased in carpentry.

Not only are the waste pipes, traps, and joints thus cut off from view where they most require watching, but the dark foul space underneath the sink is invariably utilized for the storage of cooking utensils, mops, rags, old shoes, coal oil cans, scrubbing brushes, boot blackening, grease, and other matter certainly never calculated to aid sanitary conditions.

The same might be said of the servants' hopper, which should be free from all wood work.

It should be placed where a quantity of light and ventilation can be had at all times, and not carefully and gingerly confined to a little cubby hole somewhere beneath the staircase, or in a dark unventilated closet, where it works mysteriously in a mysterious darkness.

A word with regards to the soil pipe in the basement. The best practice of the day is justly tending to do away with the burying of the soil pipe within the house, and underneath the concrete or wooden flooring of the cellar. That this was a pernicious habit it is needless to explain.

Should an obstruction of any kind take place within the house, it might necessitate the tearing up of yards and yards of flooring. And then again, a line of pipes so placed could not be tested and examined as effectually as if raised clear of the floor, and open to view. Leaks and other imperfections announcing their presence, and being detected much more readily, in the latter case.

*That all parts be of sound material, free from flaws, blemishes, or other defects, and of the kind of material best suited for their special purpose.*

In the last few years wrought iron has been introduced in the plumbing of buildings, under what is known as the "Durham system of house drainage."

The great advantages claimed by Mr. Durham, a civil engineer, for his system being that "wrought iron pipes are elastic and cannot be broken, and that when lengths are screwed together in a wrought iron coupling, the joint is as strong as any other part of the pipe; furthermore, that they will stand up vertically from a solid base to the height of any building without lateral support, and being much lighter are more easily handled."

Mr. Durham goes on to say:

. . . . "By the use of wrought iron pipes and screw-joints we construct a drainage apparatus within the building, which is gas and water tight as regards the joints; rigid, yet elastic; entirely independent of walls or floors for support, and absolutely invulnerable. As a structure it will last as long as any building will stand, and without any outlay for repairs." The thorough reliability of screw joints, and the uniformity of thickness and strength which can only be secured by the use of wrought iron soil pipes, seem to be the chief points in favour of this system.

Cast iron pipes, when of sufficient thickness, make good soil pipes. This is easily determined by their weight, and the only quality, known on the market as "extra heavy," can be safely recommended.

Even this class of pipe sometimes displays a marked unevenness of thickness on the opposite sides of a cross section, and therefore being in its weakest part no better than light pipe.

The bells on the "extra heavy" have sufficient strength to stand the caulking necessary to insure a trustworthy joint, which is not the case with the lighter class of pipes.

Lead is of course unfit for soil pipes, and should not be used even for waste pipes when a diameter of over two inches is required. For smaller waste and vent pipes, lead can be used to great advantage, for it bends, cuts, and manipulates easily.

The thickness of any lead pipe, or in other words the weight per running foot, should always be determined with reference to the work it is intended to perform.

Cast lead traps are objectionable, drawn lead being preferable for that purpose.

Traps and pipes made by hand of sheet lead, are of course out of date.

Brass is also used in ferrules and in the best forms of traps. It is also used, either polished or nickel plated, for those portions of the plumbing system that lie exposed in connection with the better class of fixtures.

Cast brass traps, such as the "Elliptic" and "Progress," manufactured by the J. L. Mott Iron Works Co., New York, are among the very best and most efficient, and to my mind a great improvement on lead traps.

Glass, when used as a portion of a trap, is objectionable, as it is so liable to break by a number of causes.

With regard to the fixtures of the system, I might say that the water closet should be of earthenware or porcelain ware, in one piece, and connected to the soil pipe by the brass flange method. Any of the numerous washout closets are good, though the more recent siphon closets, as for instance the Sanitas, and also such improved hopper closets as the "Trent wash down," are considerably better. For the respective advantages of these I must refer you to works on the subject. Baths and basins should be of porcelain ware. When a bath of this kind should be found too expensive, a "porcelain-lined iron bath" of the Imperial class will answer well; and hoppers and kitchen sinks should be preferably of English brown ware or Yorkshire ware. Porcelain-lined wash tubs are good, though they do not last like the porcelain ones.

*That the whole system be put tightly together, in the best approved manner, and possessing uniformity in strength and durability.*

This comprises a very wide and important field, for, not only must the mechanical part, *i.e.*, the cutting, bending, fitting, wiping, soldering, caulking, etc. (which go to make the Art as distinct from the Science of plumbing), come under consideration singly; but the whole work must be previously thought out, and arranged with a view to uniformity of strength and durability of the entire system. While the most approved practical methods may be understood by the scientist, it takes the practical workman to carry them out in part or in whole, and for this fact a good mechanic is indispensable. For the tightness and safety, then, of our system, we have to depend on the mechanical ability of the men we employ. No matter how scientific and commendable our plans, if the workmanship prove below the mark, miserable or defective, we must expect to meet with disappointment or failure. I therefore fail to see the force of arguments, seemingly based on the assumption that the science is everything, and the art a very secondary portion of our subject.

That this was the tendency among sanitarians in Great Britain, when sanitary plumbing received a fresh impetus some ten years ago, may be seen from the following remarks by S. Stevens Hellyer:

"If I were going to build a house for my own occupation, I should prefer the plumbing work to be done by the man who was more skilled in the science than in the art of his craft—that is to say, I should prefer a poor joint wiper to a clever one, providing that the former knew what the latter did not, viz., how to select and arrange the traps, pipes, and fittings, so that they would be 'self-cleansing'; what kind of traps to select, and how to ventilate them so that they would not lose their water seals, how to ventilate the waste-pipes, soil pipes, and drains, so that the air within them should be constantly changed—know, in short, how to execute his work on sanitary principles."

In these days of *specializing* and *high speed*, it would be almost impossible to find a man who might be considered equally competent to lay out both a system of plumbing for you, and to construct the same from cellar to attic with his own hands. We do not expect it. We do not want it. But we do insist on the joints being well wiped, the bends properly made, and the bells tightly caulked.

*That the whole system be as simple as possible and consistent with convenience, efficiency, and security.*

I think this appeals to all scientific minds, though I know of certain plumbers in this town, who, if judged by their works, certainly could not be said to agree with me in this respect.

However, I am glad to notice that there is a strong tendency towards simplification in plumbing work throughout this Continent, which will tend to make good plumbing more popular and less costly; and I firmly believe that a judicious use of anti-siphonic traps will prove one of the great factors in simplifying the house-plumbing of the future.

While I do not admit that they are preferable in *every* case, and for *all* fixtures, still I will say this, that the better kinds are more trustworthy, and less liable to get out of order, than architects and sanitarians imagine; and further, that for certain cases they are undoubtedly the only traps that meet the requirements to any degree.

Owners should be advised against such fads as, for instance, having a basin, or other fixture, placed in some remote corner of the house, and at a considerable distance from the main pipes of the plumbing system. Such arrangements greatly increase the number and complication of pipes, not to speak of the cost, and the fact that security is being sacrificed, in a measure, for trifling convenience.

At present the vent-holes in water closet fixtures are made too small. A water closet trap should be vented with nothing less than a 3-in. vent pipe, and running traps under basins, etc., should be vented with vent-pipes at least of the same size as their wastes, and in most cases a little larger diameter is preferable.

Sanitarians seem to forget that while ventilating pipes are useful in preventing the siphoning of traps, their principal work is to ventilate. Experiments have shown that they cannot do this *effectively*, unless they are made large enough.

As sink wastes have a tendency to be too large, we may therefore expect to see, in the near future, the diminution of the diameter of certain wastes, and the enlarging of certain ventilating pipes, and thereby the increasing of the efficiency of both.

*That the appliances used be economical, reliable, and adding materially to the comfort of the inmates of the building.*

In conclusion, I may say that the number of fixtures in a dwelling should be kept down as much as possible. Not merely from a consideration of economy, but from the more important standpoint of health. The oftener traps are used the better. Where a house has a large number of basins, some may be rarely used, and their traps are liable to evaporate away. Wherever overflow-pipes can be done away with, it is for the better.

Basins provided with the Boston plug, which acts both as a plug and as an overflow waste in itself, are the best fixtures of the kind on the market to-day. Wastes from refrigerators, cisterns, safes, etc., of course should never be connected directly to the plumbing system, but all these secondary points are well treated in any of the more recent books on the subject.

After all, the underlying principle of "sanitary plumbing," is to secure such an arrangement of pipes, traps, and fixtures, that any solids, liquids, or gases can readily and speedily find an entrance into the plumbing system, at any of the openings in the house; but that, having once gained an entrance, they can never-more return to injure the health of the inmates of that dwelling. When this fundamental principle is thoroughly understood, it should not prove a hard task to determine upon a Sanitary system of house drainage.

# HOT WATER HEATING.

By W. H. Shillinglaw, Brandon, Man.

In writing this paper, I do not pretend to give anything new on the subject of heating by hot water; but only describe the system as it has come under my own notice and direction, with some of the principles on which it works.

First:—The different systems used for heating buildings, the principal of which are: Hot Air, Steam, and Hot Water.

The most common method of warming buildings, and perhaps the most economical, where the buildings are small or where a uniform temperature is not required throughout the building, as in churches, schools, and dwellings, is the hot air furnace. This consists of a fire-box cased with iron or brick, enclosing a chamber for heating air, from which pipes carry the heated air to the various apartments.

Steam heating is now only used where there is a steam plant in connection with the building to be heated, and where exhaust steam from the engine can be used. The apparatus consists of a boiler to generate the steam, and the necessary pipes to convey the steam to the coils or radiators in the building.

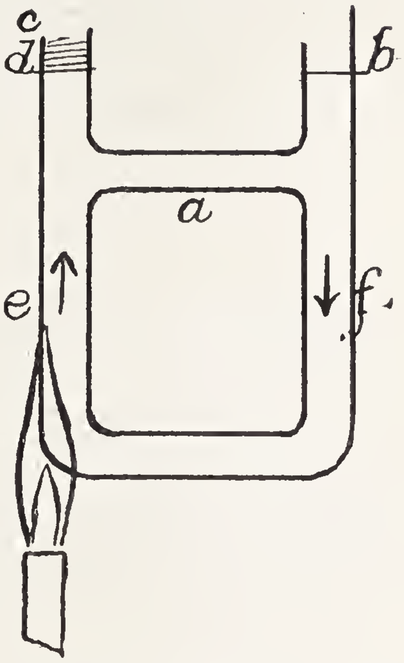
Hot water is generally used here, where a complete system of heating is required, and is fast taking the place of other systems even in the smaller buildings. The apparatus consists of a heater and the necessary flow and return pipes or mains, etc., to connect with the coils or radiators in the apartments to be heated.

There are two causes for the circulation of water in vessels: one—the subtraction of heat; the other—the addition of heat. I have heard of one other (I will give it to you for what it is worth)—water itself won't expand, but the air contained in the water expands and thus causes circulation.

The first may be observed in a closed glass vessel filled with hot water and allowed to cool, when the particles in contact with the sides of the vessel become cooler by giving off their heat to the surrounding air. Cold water is denser than hot water, and falling, displaces the hot water, which rises up the centre of the vessel.

The second may be observed in an ordinary test tube heated over a flame, where the heated particles rise in the centre of the tube and are replaced by the cooled particles falling. In this case, heat, or its mechanical equivalent, is the force employed to overcome gravity, and is the cause of circulation of hot water in a system of pipes.

A simple apparatus, as in figure, will illustrate the circulation of water in a hot water system, in which *e* and *f* represent the flow and return pipes; *c*, expansion tank; and *cd*, head caused by expansion. The velocity of the flow of water in a system of pipes, is due to the head caused by the expansion of the water in the heater and the pipes. This is the theoretical velocity, and allowance must be made for friction in the pipes, bends, valves, etc., and loss by entry into pipes.



For the flow of water into and through pipes, loss of velocity from friction, bends, etc., I will refer you to Hydraulics.

Baldwin (pages 42 and 43) gives diagrams by Dalton to show the expansion of water between 40° and 212°, for a height of 10 ft., and the velocity of the flow of water in feet per second, when the height from which it falls is known. These diagrams are used together. For example, take an apparatus 10 ft. high in which the water enters the flow pipes at a temperature of 182°, and returns at 162° to boiler. What should be the greatest possible velocity of the water in the flow pipe?

By diagram A for a temperature of 182° we have a head of 3.49 in.; for a temperature of 162° a head of 2.69 in., or a difference of head of .80 in. By diagram B, approximating .80 on the vertical scale, a horizontal line drawn from it will cross the curve where the 2 ft. velocity line cuts it; or, for a head of .80 in., we have a theoretical velocity of 2 ft. per second. Having made the necessary allowance for friction, etc., from this velocity, the diameters of the pipes necessary to deliver the required amount of water to the radiating surface can be obtained.

In planning a hot water system, the first thing to consider is the radiating surface required, and this can only be decided on from the nature of the outside walls of the building, condition of windows and doors, and we must have a good conception of the amount of heat lost through windows, walls, etc., and the amount of heat given off by the radiating medium. For the methods of proportioning radiating surface, I give the following rules, and will refer you to Baldwin's Hot Water Heating, for further information that you will require.

The common method used is to allow a percentage of one in. pipe to cubic space. Baldwin gives the following rule (page 86): "Divide the difference in temperature between that at which the room is to be kept and the coldest outside atmosphere, by the difference between the temperature of the steam (or water) pipes and that at which you wish to keep the room, and the quotient will be the square feet or fraction thereof of plate or pipe surface that is the equivalent of each square foot of glass or its equivalent in transmitting power."

For example, $t$ = required temperature of room.
$t^1$ = outside temperature.
$T$ = temperature of water in radiator.

Then $\frac{t - t^1}{T - t} = r$, ratio of radiating surface to glass surface. Say $t = 70°$, $t^1 = 30°$, $T = 140°$, then $r = .57$.

But for a climate where a thermometer reaches as low as $-40°$, it is necessary to have a greater allowance for this ratio, which may be obtained by giving $t^1$ a value 0°, which will give $r = 1$, for a temperature of 140° of water in radiator, so that for temperatures below 0° the heat of the water in pipes may be increased, or for $-40°$, $T$ would be $\frac{t - t^1}{r} + t = 10°$, the temperature of water required in radiator.

To this ratio of one of pipe or plate surface to one of glass or its equivalent of wall surface, from 10 to 50 % must be added for warming air admitted accidentally, and for loss of heat by other sources than walls and windows, and the allowance to be made will depend on the character of the building and the judgment and experience of the designer. In this method, from 7 to 12 feet of wall surface are taken as equal to one foot of glass surface, and the amount of radiating surface is computed from glass surface.

In *The Engineering Record* of Nov. 29 and Dec. 13, 1890, in an article by R. C. Carpenter, of Ithaca, N.Y., the following formula is given:

$s = \frac{7}{15}\left(\frac{1}{70}c + .11w + 1.5g\right)$, in which
$s$ = radiatory surface required.
$c$ = cubic contents of room.
$w$ = no. of windows and doors.
$g$ = glass surface. The fraction $\frac{7}{15}$ is obtained as follows:
$\frac{2}{3}\left(\frac{t - t^1}{T - t}\right)$ in which $t = 70°$, $t^1 = 0°$, $T = 170°$.

But this is for a climate where 0° is considered a fairly low temperature, or for temperatures experienced here.
$t = 70°$, $t^1 = 0°$, $T = 140°$, then $\frac{7}{15}$ becomes $\frac{2}{3}$. (See *Engineering Record* of above dates).

By the "percentage" method, a certain percentage of the cubic capacity of the room is taken in one inch pipe. This is the simplest and most commonly used here. The usual allowance is 8 to 10% for ground floors, 6 to 8% for first floors, etc., depending altogether on the kind of building and location of the rooms. I give an example in illustration of the different methods, which will show how they will correspond with each other; in some cases they give widely different results.

| BALDWIN. $S = 1.10$ to $1.5g$. | | | | CARPENTER. $S_1 = \frac{2}{3}(\frac{c}{70} + 11w + 1.5g.)$ | PER CENT. METHOD. $S_2 =$ 10 to 8%. *3 ft. of 1 in. pipe = 1 ft. surface.* |
|---|---|---|---|---|---|
| *No. of Room.* | *Cu. ft. = c.* | $g$ | $S$ | $S_1$ | $S_2$ |
| No. 1 | 2093 | 45 | 68 | 72 | 69 |
| No. 2 | 1990 | 36 | 62 | 62 | 66 |
| No. 3 | 2210 | 72 | 96 | 108 | 74 |
| No. 4 | 3510 | 72 | 99 | 120 | 117 |
| No. 5 | 1729 | 130 | 170 | 162 | 58 |
| No. 6 | 2080 | 67 | 67 | 98 | 69 |

These rooms are on first floor, and have a west and south front, but the calculations are based on ground floor allowance. The walls are 17 in. solid brick, back plastered, strapped, with plastered three-coat work. Frames are boxed and well packed; glass, plate (glass surface is given for size of opening in brickwork); ceilings 13 feet. The above table will show some of the difficulties in proportioning a hot water system, and shows further how much depends on good judgment and experience in the use of formulæ of any kind.

By the "percentage" method, which deals only with cubic capacity, allowance must be made where the cubic capacity and outside wall area are disproportionate; take, for example, rooms Nos. 4 and 5, in which the proportion of outside wall area to cubic capacity is $\frac{1}{22}$ and $\frac{1}{5}$ nearly, yet this method gives 117 and 58 feet as heating surfaces required, or the room with least cooling surface has the greatest heating surface. Of course in practice No. 5 would be given more surface, but No. 4 would most likely be unchanged, the result in both cases being wrong.

By the other formulæ this is reversed.

The following conclusions may be drawn from this table:

1. The percentage method gives a quantity which may be too large or

too small in itself, but from which, by the use of good judgment, the nearly correct amount of heating surface can be decided.

2. Carpenter's formula gives the heating surface based on outside and inside temperature, temperature of surface, number of openings, cubic capacity, and glass area : but omits actual wall surface, which he says will have but little effect.

3. Baldwin's formula gives heating surface, based on outside and inside temperature, temperature of surface, glass area, with wall area reduced to glass area ; but omits the cubic capacity. This leaves the value of $r$ to be chosen by the designer, and experience will enable almost any one to put a sufficiently accurate estimate on this item.

I am not prepared to say which is the best method of the above three, but I think Carpenter's would give the best results, as it deals with the quantities which will most affect the heating of a building. I know of no work proportioned by any except the percentage method. For upper floors, by the percentage method, a decreasing scale of values is used as the height increases. By the other methods, the amount of surface is not decreased ; but the amount of water supplied is regulated by decreasing the size of pipes, and inlets and outlets of radiators. There is little use of my giving you the methods of doing this, as the diameters of inlets to radiators, coils, etc., are fixed by commercial sizes—1¼ in. being the common size. For smaller sizes, these require to be reduced by bushing.

Diagrams are given by Baldwin (chap. 14 of Hot Water Heating) for the purpose of determining the diameters of supply pipes to radiators. In practice, the hot water fitter uses his own judgment as to different sizes of radiators and heights above boiler. Of course in running horizontal mains, allowance must be made for length of main, connections, etc.

The main pipes and systems of piping used in the warming of buildings by hot water may be classed under two heads, as simple or single circuits and compound circuits.

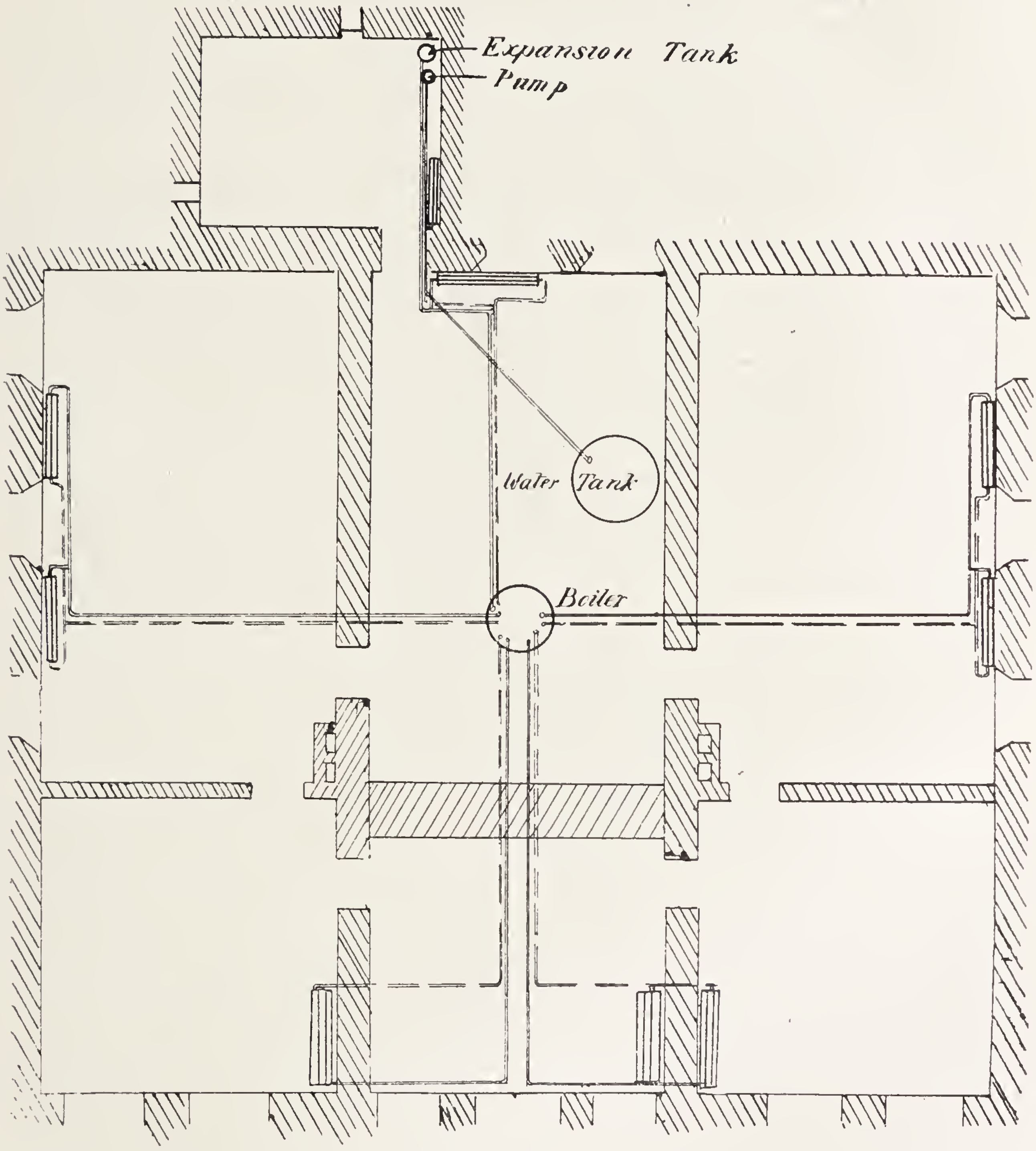
A single circuit system has no branches, but the flow and return pipes supply but one coil or radiator.

A compound circuit system has branches taken off a main supply pipe to feed the coils and radiators.

A single circuit system is of course the easiest to put in, as in any case the circuit cannot but work ; but will not in a compound circuit, unless the main is of sufficient capacity to supply the circuit throughout. There is one danger in this system, of the water taking the shortest circuit, which can only be overcome by proper proportioning of the entire system.

I will give a short description of the accompanying drawing.

This is to all intents a simple circuit system, although two radiators are supplied from one flow pipe, but as the branches are of equal length and radiators are on the same level, there is no difficulty in the supply. The boiler is a Gurney of 3000 feet of one inch pipe capacity. Radiators used are Gurney's make. The boiler is located in the basement in the centre of building, which is only one storey. The expansion tank is in room at rear, and about twelve feet above boiler. The drawings will give you all information as to size of pipes, etc., each circuit having draw-off cocks. The building is constructed very similar to an ordinary vault—walls 24 inches thick, with hollow space, and plastered directly on brickwork; roof, a three ring brick arch over each section. All frames and doors are iron. Height of ceiling 16 feet.



LAND TITLES OFFICE.

In the Fleming block this system was put in by the "percentage" method, the contractor being required to guarantee the boiler capacity and pipe system. This method of putting in hot water apparatus is generally adopted here, and which, I think, should be done away with as soon as possible; although it takes a great deal of the responsibility out of the architect's hands, yet it seldom gives satisfaction to anyone. Even if the radiating surface is properly proportioned, the supply may not be sufficient for the work to be done on account of mains, etc., being too small.

I had this difficulty in connection with this work. Taking mains Nos. 1, supplying wholesale department, and 2, supplying west section of building; wholesale, 966 feet of surface; west section, 1352 feet. It was the original intention to supply these by a 3 inch and a 4 inch main respectively. This was altered, a 4 inch main being now used for wholesale, and about 1176 feet of west section being put on a 4 inch main and the remainder on a 2 inch. The reason for putting in the smallest mains that will supply the system, is to save money in construction—one of the evils of allowing the hot water contractor to proportion his own piping. The result of insufficient main supply will show itself in coal consumption, when required to force the system in very cold weather. In a country where the only hot water engineers are contractors and competitors as well, it shows how important it is that the architect should make this ever increasing demand for heating, one of the most important branches of his work.

In these two systems, all mains are valved with Peet valves at boiler, and provided with draw-off cocks, so that any one main can be used independently of the others. Each rising line of pipe, supplying radiators, from main is valved and provided with draw-off cocks as well, giving almost complete separation for any circuit or branch circuit. The boilers used are the Plaxtow Boiler, made in Galt by MacDougall; Gurney radiator and inch pipe coils giving heating surface. I am unable to add anything regarding the results to be obtained from this system, for two reasons: (1) The apparatus was put in in the middle of winter, before the building was plastered, and during our coldest weather only a small section was in use. (2) We have had no cold weather to give, what is considered here, the boilers a good trial. I should like to have been able to have attached such results as, coal consumption, temperature from radiators, including their location, supply, etc., difference of temperature between flow and return, etc., etc., as these taken together with drawings would give a better idea of what is required in a hot water system, than a mere paper as to what should be put in.

# THE FUNDAMENTAL PRINCIPLES OF MECHANICS.

By J. A. Duff, B.A., Grad. S.P.S., Fellow in Engineering.

In childhood, a very definite conception is formed of matter, space, and time. It is observed that bodies which are not fixed to the earth frequently change their position relatively to it, and that the earth and other bodies are continually changing their position in space.

The change of position of a body is called its displacement, and is measured by the distance between the two positions of the body. When a body is being displaced, it is said to be in motion. The term motion involves the time occupied by the displacement as well as the space traversed. Two motions are not equal unless both the displacements and the times occupied by the displacements are equal. When a body is moving uniformly, the displacements during equal intervals of time will be the same. It is, however, observed that bodies do not always move uniformly, and enquiry should then be made into the cause of any change of motion which may take place.

If, by our own exertions, we change the motion of a body, we ascribe the cause to our muscular power or force; accordingly, the term *force* is applied to any cause which may change the motion of a body.

The science of Dynamics is the investigation of the relations existing between the forces acting upon a body, the body itself, and the motion which would ensue. On account of our ignorance of the exact nature of the molecular actions which take place in natural bodies, the complete solution of the problem of Dynamics is impossible. It has accordingly been found necessary to make certain assumptions concerning the constitution of matter, by means of which a solution of the Dynamical problems is possible. Although these assumptions are only approximately true, the results obtained are sufficiently accurate for most purposes. For example, the deformation of ordinary solids under ordinary forces is very slight, and it is sufficient in many cases to assume that there is no deformation at all; thus all reference to molecular action is avoided, and yet the results are sufficiently accurate.

Before entering upon the whole question of Dynamics, it is customary to make a special study of the relations existing between forces without reference to the ensuing motion, and a study of motion without reference to the cause. The latter of these investigations is called *Kinematics:* the former, *Statics.*

Statics literally means the science of equilibrium, but its province has been enlarged so as to include all investigations concerning force in which the motion of the body is not considered.

The term *Mechanics* is frequently employed to embrace the three sciences, Statics, Kinematics, and Dynamics. It is used in this sense in the title of the present paper.

Dynamics being the investigation of the relations existing between force, matter, and motion, and motion involving both time and space, dynamics involves time, space, matter, and force. These may be called the four fundamental ideas of Dynamics.

In Statics, the idea of time is eliminated, and we are concerned only with force, matter on which force acts, and space in which matter exists, and through which force acts. In Kinematics, the idea of force is eliminated, and we are concerned only with matter, motion of matter, and space in which motion takes place and matter exists. These results may be tabulated as follows:

| | |
|---|---|
| MECHANICS (Sometimes also called Dynamics). | *Statics*, treating of matter, space, and force. |
| | *Kinematics*, treating of matter, space, and time. |
| | *Dynamics*, treating of matter, space, time, and force. |

The ideas of space and matter are never entirely eliminated, but each of the above sciences is subdivided according to assumptions which may be made regarding matter and space. Thus there is the Statics, Kinematics, and Dynamics of a particle, of a rigid body, of an incompressible fluid, or of an elastic solid or fluid body; and each of these is treated separately, according as space is assumed to consist of one plane, of a series of parallel planes, or of indefinite extension in every direction.

### KINEMATICS—*motion*.

The rate of motion of a body is called its *velocity*, and is measured by the displacement per unit of time. Space and time are concrete quantities whose units of measurement may be chosen independently. Hence the expression for the velocity of a body will vary with every change made in the unit of space or time, and the velocity will not be completely given unless the units of time and space are both given. It follows at once that two velocities cannot be combined in any way unless both are expressed in the same units of time and space.

Displacements measured in any given direction must not be considered as identical with the same lengths measured in another direction. Therefore, in order that a displacement may be completely defined, its direction and sense, as well as its magnitude, must be given. In the same manner, a velocity (which is the ratio of a displacement to a time) must be given in magnitude, direction, and sense in order to be completely defined.

Any quantity which may be specified by magnitude, direction, and sense is termed a *vector quantity.* Any vector quantity may be represented by a finite straight line, because magnitude, direction, and sense may be thus represented. Displacements and velocities, being specified by magnitude, direction, and sense, are vector quantities, and may be represented by finite straight lines.

If the motion is such that the velocity is always the same, it is said to be uniform or constant. If the velocity changes from time to time, it is said to be variable.

The average velocity during any interval is the ratio of the displacement to the interval. If the velocity vary continuously, that is to say, if in passing from one value to another it successively assume every intermediate value, then the shorter the interval the less will be the difference between the extreme velocities; and the less, also, the difference between the actual velocity and the average velocity during the interval. The interval may be made so small that this difference will be less than any assignable quantity: in other words, if the velocity vary continuously, by taking the interval of time indefinitely small, the velocity during that interval may be considered uniform, and the actual velocity may be expressed by the average velocity during the interval. Accordingly, if $\delta s$ is the distance traversed during a time $\delta t$, the velocity is expressed by $\frac{\delta s}{\delta t}$.

The rate of change of velocity is called *acceleration*, and bears the same relation to change of velocity that velocity bears to displacement, or change of position. Acceleration may be either uniform or variable; the average acceleration during any interval is measured by the ratio of the change of velocity to the interval. Since an acceleration may be specified by magnitude, direction, and sense, it is a vector quantity, and may be represented by a finite straight line.

One of the most important problems in kinematics is the composition of velocities, or the determination of the single velocity, which is equivalent to two or more velocities acting simultaneously. This single equivalent velocity is called the *resultant.* But before determining the resultant velocity, let us examine the similar problem for displacements.

The displacement of a body depends only on the velocity and the duration of the motion, and not upon the time at which motion occurs. Accordingly, the displacements under consideration, although occurring simultaneously, may be supposed to take place in succession, in any order.

Let the vector of that displacement which is supposed to take place first be drawn: from its extremity let the vector of the second displacement be drawn, and so on; in this manner a polygon is formed of the displacement vectors. The resultant displacement is evidently represented by the straight line joining the initial to the final point of this polygon.

In like manner, velocities may be supposed to act in succession; and when all the velocities have acted for the given interval of time, the body will be in the same condition as if the velocities had acted simultaneously. Accordingly, if the vector of one of the velocities be drawn, and from its extremity the vector of another, and so on, a polygon will be formed of the vectors of the several velocities, and the straight line joining the initial and final points of this polygon will be the vector of the resultant velocity.

Again, if it is desired to find the resultant of several accelerations, construct the vector polygon for the accelerations, and the straight line joining the initial to the final point will be the vector of resultant acceleration.

## STATICS—*force.*

A force is completely specified when its magnitude, direction, sense, and point of application are given. In so far as it involves magnitude, direction, and sense, a force is a vector quantity, and may be represented by a vector line.

The vector of the resultant of a set of forces is (by the analogy of other resultant vectors) the straight line joining the initial to the final point of the vector polygon. This theorem, which is the basis of the science of Statics, is frequently deduced by means of Dynamical considerations. According to Newton's Second Law, "change of motion is proportional to the impressed force, and takes place in the direction in which the impressed force acts." In other words, a velocity or change of velocity is the same in direction and sense, and is proportional in magnitude to the force which causes it.

It follows that the vector of a velocity may be made to represent a force by simply changing the unit of measurement. Hence all theorems concerning velocity vectors are true also for force vectors. But it has been shown that the vector of the resultant velocity is given by the straight line joining the initial to the final point of the vector polygon. Accordingly, if the scale be changed from velocities to forces, the vector of the resultant force is given by the straight line joining the initial to the final point of the vector polygon. If the direction of the forces all pass through one point, the resultant will evidently pass through that point; but if the directions of the forces do not all pass through one point, a further investigation will be required to determine a point on the line of action of the resultant—an investigation for which there is not space in the present paper.*

If a set of forces are in equilibrium, there will be no change in the motion of the body on which they act. Recurring to the Dynamical law, that "change of motion is proportional to the impressed force," it follows that in order to have equilibrium, or no change in the motion, the set of forces must be reducible to a single resultant, which is zero.

### DYNAMICS—*force, mass, motion.*

Although such properties of matter as the size, configuration, and elasticity of bodies are considered in Statics and Kinematics, the *quantity of matter* in the body is not taken into account. The *quantity of matter* in a body is called its *mass*, and is measured by the motion produced by a certain force. Hence, it is only in Dynamics, where force and motion are considered conjointly, that any reference could be made to *mass*.

The relations known to exist between time, space, matter, and force are usually expressed by certain physical laws, known as Newton's Laws of Motion. The proof of these laws rests in the fact that every logical deduction from them, which man has been able to test by experiment or observation has been found to be true. It is upon these laws that the science of Dynamics should be based.

The First Law is: "*Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it may be compelled by impressed forces to change that state.*" If no forces act on a body, it will continue to move with whatever motion it had at the moment when all forces ceased to act upon it. The algebraic expression for the First Law is:

$$\text{If } F = O, \text{ then } \frac{ds}{dt} \text{ is a constant,}$$

$$\text{or, } \frac{d^2 s}{dt^2} = O.$$

The Second Law is: "*Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force acts.*" The term *motion* is not employed here in the same sense as in Kinematics, where the ideas of force and mass are not introduced, but signifies the *quantity of motion*, or the momentum of the body, which is measured, according to Newton, by the product of the *mass* and the *velocity*. Change of motion will be measured by the change in this product, or, if the mass remains constant, by the product of the mass into the change in the velocity.

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*See paper on Diagrams.

Again, if $F$ is the measure of a force acting through one unit of time, $Ft$ will be the measure of the same force acting through $t$ units of time, because the effect of any force is proportional to the time during which it acts. Therefore, according to the second law, $m_1v_1 - m_0v_0$ is proportional to $F\ (t_1 - t_0)$ when $m_0v_0$ is the quantity of motion in the body at the time $t_0$ and $m_1v_1$ the quantity of motion at the time $t_1$. By suitably choosing the units of *force* and *mass*, the above proportion may be reduced to an equation. If the mass remains constant during the interval, and the units be suitably chosen, then

$$m\ (v_1 - v_0) = F\ (t_1 - t_0) \qquad (1)$$

is the algebraic expression for the Second Law. If the body start from rest at the beginning of the interval, the equation reduces to

$$mv = Ft. \qquad (2)$$

In Dynamics there are two systems of units for measuring *force* and *mass*, and this sometimes gives trouble to beginners, though not on account of any real difficulty. Both systems are chosen in such a manner as to reduce the expression for the second law of motion to an equation. If, for simplicity, we consider the motion of a body starting from the rest, the units are made subject to the condition

$$mv = Ft \qquad (2)$$

If the unit of each quantity be taken, this equation becomes, unity equal to unity. The units of any three of the quantities may be chosen arbitrarily; that of the fourth will then be determined in accordance with the above condition. The unit of time may be taken as one *second*, the unit of distance as one *foot*, and therefore the unit of velocity as one *foot per second.* Thus, if the unit of mass is taken as the *imperial pound*, the unit of force must be (equation 2) *that force which, acting on one pound of matter during one second, generates in it a velocity of one foot per second.* This is called the Absolute Unit of Force.

The most familiar of forces, as well as the one which furnishes the most convenient means of measuring force, is the Attraction of the Earth. It is most natural that the attraction of the earth on some definite quantity of matter should have been chosen as the unit of force. The quantity of matter thus selected in the British countries is the *imperial pound*—the same body which in the Absolute system is taken for the unit of mass. With the pound for the unit of force, and the same units of space and time, the unit of mass must be (equation 2) *that mass which, when acted upon during one second by a force of one pound, will acquire a velocity of one foot per second.* This is called the Gravitation Unit of Mass.

Experiment has shown that any body falling unresisted to the Earth will acquire in one second a velocity which may be taken as 32.2 feet per second. Accordingly, if a force equal to the attraction of the earth on one pound (which is the Gravitation unit of force) act upon one pound of matter for one second, it will generate a velocity of 32.2 feet per second. Or, if the same force act upon a mass of 32.2 pounds, it will generate a velocity of one foot per second. This is the condition to be fulfilled by the Gravitation Unit of Mass, which is therefore taken to be 32.2 pounds. Again, if a force equal to $\frac{1}{32.2}$ of the attraction of the earth on one pound act on a mass of one pound during one second, it will generate a velocity of one foot per second. This is the condition to be fulfilled by the Absolute unit of force, which is therefore taken to be $\frac{1}{32.2}$ of a pound. Hence in the Gravitation system the unit of force is one pound, and the unit of mass is 32.2 pounds; in the Absolute system the unit of force is $\frac{1}{32.2}$ of a pound, and the unit of mass is one pound.

It must be remembered that the word *pound* is used in two different senses—as a measure of mass, and as a measure of force.

It may also be remarked that the units of the Gravitation system are each 32.2 times larger than those of the Absolute system, and that in both systems the unit of mass is 32.2 times larger than the unit of force.

In the equation $m\,(v_1 - v_0) = F(t_1 - t_0)$ (1)

If $F = o$, then $m\,(v_1 - v_0) = o$ (3)

That is to say, if there be no force acting on the body, there will be no change of motion or momentum, and the body will continue in its state of rest or of uniform motion in a straight line. Thus the First Law of Motion is the particular case of the Second, in which the impressed force is zero.

In the case in which the applied force changes the direction but not the magnitude of the motion, equation (1) apparently fails to represent the Second Law of Motion. The left-hand side vanishes because $v$ is algebraically equal to $v_0$, but the right-hand side is evidently not equal to zero. The explanation is that $v$ is a vector quantity, and involves direction as well as magnitude. If $v$ is to be used in the restricted sense of an algebraic quantity, then $F$ must be restricted to *the resolved part of the force* in the direction of the motion. Then when the direction but not the magnitude of the motion changes, the resolved part of the force in the direction of the motion becomes zero, and the force acting on the body is at right angles to the motion.

The Third Law of Motion is: "*To every action there is always an equal and contrary reaction; or the mutual actions of any two bodies are always equal and oppositely directed in the same straight line.*"

The primary meaning of this law is: "*With whatever force one body* *acts upon another, the second body will react upon the first with an equal force in the opposite direction.*" That the effect of the action and reaction appears at times to be quite incomparable is due to a disparity in the bodies acted upon and not in the forces themselves.

It follows that no force can exist alone, but must always be accompanied by one of the same magnitude, though opposite in sense, emanating from the body on which the first force acts. Therefore every force which acts between two members of a system has another force inseparably connected with it which counterbalances it when the motion of the whole system is taken into account; and the motion of the system, as a whole, is not affected by these internal forces or by any motion caused by them.

If another meaning be given to the word *action*, this law is capable of another interpretation.

After defining the velocity of a force or resistance to be the velocity of the point of application of the force resolved in the direction of the force, Newton makes the following statement: "If the Action of the agent be measured by its amount and its velocity conjointly, and if, similarly, the Reaction of the resistance be measured by the velocity of its several parts and their several amounts conjointly, whether these arise from friction, adhesion, weight, or acceleration—Action and Reaction in all combinations of machines will be equal and opposite." The *action of the agent* is the product of the force and the resolved part of the velocity of its point of application in the direction of the force—a product which is now called the rate at which the agent works, or the power of the agent.

Prof. Tait has translated Newton's statement into modern scientific language as follows: "Work done on any system of bodies (in Newton's statement, the parts of a machine) has its equivalent in work done against friction, molecular forces, or gravity, if there be no acceleration; but, if there be acceleration, part of the work is expended in overcoming the resistance to acceleration, and the additional kinetic energy developed is equivalent to the work so spent." It will be observed that this is a definition of the Law of the Conservation of Energy. Accordingly, Newton's second interpretation of the Third Law of Motion may be considered as an imperfect statement of the great principle of the Conservation of Energy.

If $F_1$ be the force which one body exerts on another, and $F_2$ the force which the second body exerts on the first, then according to the first interpretation of the third law

$$F_1 = -F_2$$

$$\text{or,}\quad F_1 + F_2 = O \qquad (4)$$

Equation (4) furnishes no relation between the four fundamental ideas of Dynamics.

The second interpretation of the law as enunciated by Prof. Tait may be expressed algebraically thus:

$$\Sigma(Ps) - \Sigma(Rs) = \Sigma(\tfrac{1}{2}mv^2) \qquad (5)$$

Where $\Sigma(Ps)$ is the sum of the products of each of the acting forces into the displacement of its point of application in its own direction; $\Sigma(Rs)$ a similar sum for resistances; $\Sigma(\frac{1}{2}mv^2)$ the sum of the kinetic energies developed.

If the system consists of only one rigid body, equation (5) reduces to

$$Ps - Rs = \tfrac{1}{2}mv^2 \qquad (6)$$

Writing $F$ for the resultant of the acting and resisting forces, equation (6) becomes

$$Fs = \tfrac{1}{2}mv^2 \qquad (7)$$

Equation (7) is the familiar expression for the kinetic energy of a body starting from rest under a force $F$. Its first differential equation is

$$Fds = \tfrac{1}{2}d(mv^2) = mv\,dv. \qquad (8)$$

Hence $$F\frac{ds}{dt} = mv\frac{dv}{dt}$$

But $$\frac{ds}{dt} = v$$

$$\therefore F = m\frac{dv}{dt}$$

or, $$F\,dt = m\,dv \qquad (9)$$

From equation (8) *force* may be defined as the *ratio* which the change in the kinetic energy of a body bears to the distance through which the force acts. Thus force is a mere ratio analogous to velocity, and has not necessarily objective reality any more than velocity has. Speaking of force, Prof. Tait says: "What is really observed is either a transference or a tendency to transference of what is called energy from one portion of matter to another; whenever such a transference takes place, there is relative motion of the portions of matter concerned, and the so-called force in any direction is merely the *rate of transference*, or of transformation of energy per unit of length for displacement in that direction." It may be asked, "Why not consider energy a fundamental idea or concept instead of force?" Energy is generally conceded to have objective existence, and it possesses the important property of indestructibility or conservation, whilst force is generally conceded to be devoid of this property.

Force, *the ratio*, has been selected instead of energy, *the thing* whose ratio of transference force is, because it has been customary to begin with force and lead the student up to a consideration of energy. The idea of force is more familiar to and more easily understood by a beginner than that of energy, and many of the propositions concerning force were well known long before the existence of energy was suspected.

It must be noted that transference of energy is *the cause* which alters a body's state of rest, or of uniform motion in a straight line, and that *force* is merely *the rate* at which this transference takes place. Hence the usual definition of force requires to be slightly modified.

Equation (9), which is derived from a particular case of the equation of energy, is the differential form of equation (1), which expresses the Second Law of Motion, and accordingly the Second Law of Motion may be deduced from the Law of the Conservation of Energy. It has been shown that the First Law is a special case of the Second, and that the Third is an imperfect expression of the Law of the Conservation of Energy; therefore Newton's Laws are not separate and distinct, but may all be included in and deduced from the Third, or its modern equivalent, the Conservation of Energy.

It is to be expected, then, that Newton's Laws, though three in number, will furnish only one independent relation between the four elements of Dynamics. The simplest form of this relation is given in equation (1). Any arbitrary values whatever may be assigned to any three of these quantities, and the corresponding value of the fourth determined from the most convenient form of the above relation. The object of Dynamics is to make this determination. Every problem in Dynamics is nothing more than a different form of the one general problem: *Having given three elements, to determine the fourth, or of the cognate one, to determine if certain given values of the four elements are consistent with the Laws of Motion.*

PATERSON, N.J., January 10th, 1891.

# EARTHWORKS ON ROADS AND RAILROADS.

### By C. H. Mitchell.

*Mr. President and Gentlemen,*—Earthworks are built for a certain purpose, and that purpose to sustain a load put on them in some manner. Like other structures, they are liable to injury or collapse, and it is necessary for the engineer to examine how best to prevent this. The greatest obstacles he has to surmount are presented by nature, but most frequently these can be avoided with a little care bestowed at the right time and place. Unless a good construction be followed by a good maintenance, the required end is seldom attained, so it is best to be careful in construction and the maintenance will not give much trouble.

With respect to the location of a piece of earthwork, there are a number of things to be remembered, and some of these might be briefly enumerated:

(1) Avoid cuttings or embankments in treacherous soil as much as possible, and especially if on a hillside.

(2) In exposed places in hilly districts find which side of the valley the snow remains longer, which receives more sunshine and wind, and which is better wooded.

(3) The destruction of an embankment may be caused by its obstructing natural watercourses of any kind.

(4) A road is safer on the side of a valley which is freer from watercourses.

Many other conditions might be mentioned, but space will not permit.

Proceeding next to the general considerations governing the construction of the slopes of cuttings or embankments, and determination of the permanent stability of any earth, it is always the *surface* of the embankment or cutting which will be first affected by the natural agencies. Experience has shown that different earths will repose safely at different inclinations, and on this basis an approximate set of tables of inclinations for earthworks of all kinds has been compiled. However, it will be apparent that these tables should not always serve as absolute guides in practice, for so much depends upon the accompanying circumstances and local peculiarities. By an inspection of the surrounding district, an approximate idea of the stability and peculiarities of the different earths occurring in the vicinity of the proposed work may be obtained. These points, associated with the information derived from a set of tables, will usually enable one to arrive at a satisfactory arrangement of slopes. Just here a table of range of inclinations of several of the more frequently occurring earths may be inserted :

| | |
|---|---|
| (1) Alluvial soil (loamy earth, clay, and 40 to 70% sand) | 1½ to 1 TO 2 to 1 |
| (2) " " (clay loam, clay, and 30% sand) | |
| (3) Solid clay mixed with fine sand | 2 TO 1 |
| (4) Solid blue clay, marl, etc. | 1½ to 1 TO 2 to 1 |
| (5) Fine dry sand | |
| (6) Firm shale, surface protected | 1 TO 1 |
| (7) Clean gravel | 1½ TO 1 |

Here it will be seen that the slopes most generally adapted for ordinary earths in cuttings and embankments range from 2 to 1 TO 1 to 1.

In ordinary earths frictional resistance is the chief factor of stability. The amount of this resistance depends of course altogether upon the material and the conditions attending, as moisture, irregularity of character of soil, the process of excavation or deposition, etc. As for the moisture, it is found that the resistance is reduced by from 10 to 25 % for different materials when they are wet. Tables of frictional resistance for different earths have been prepared, by which means a slope can be partially determined. For ordinary earths, this co-efficient of friction ranges from 0.25 to 1.00. Consequently the slope of repose, say $S$ to 1, is found by the expression $S = \frac{1}{F}$ where $F$ is the co-efficient of friction. Hence in above cases

$$S = \frac{1}{0.25} \text{ to } \frac{1}{1} = 4 \text{ to } 1 \text{ TO } 1 \text{ to } 1.$$

However, this is absolute, and does not make allowance for the above-mentioned conditions of irregularity in the material and construction. If it were possible to build a piece of earthwork in which the material would always remain as originally built, the slopes could be mathematically determined, knowing the co-efficients of friction and cohesion. But in determining the inclination, it is not so much the angle at which the artificial surface will stand, at, or a short time after being built, for this is not the object; but the question to be answered is, "What will be the approximate position which will permanently remain so as to prevent movement?" This chiefly depends upon the material, exposure to weather, water, vibration, and the height or depth, as the case may be. In all earth where the cohesion is small a straight slope is the best, for it has an even surface, which prevents the accumulation of water, and it also offers the least surface to the weather; but in material where the cohesion is considerable, the slope, as a rule, which is naturally assumed is curved. This conclusion was originally arrived at by an investigation of the laws of pressure in connection with the theoretically correct slope, and has since been corroborated by experiment; for it has been found that in high embankments especially the slope assumes a considerable curve after it has been allowed to weather and settle. If you notice a slip in an embankment of earth, you will in all probability find that the upper portion of the new or exposed surface is concave, whilst the lower portion is slightly convex, being caused by the upper portion falling, and the lower part, while receiving it, being pressed outward. This principle is very frequently followed in high embankments of treacherous soil, making, for an example, the following slopes for an embankment 60 feet high and of formation width 24 feet:

| | | | | |
|---|---|---|---|---|
| Upper 20 feet at a slope of | | | | 1½ to 1 |
| Middle 20 feet | " | " | " | 2 to 1 |
| Lower 20 feet | " | " | " | 3 to 1 |

The next point is that of the approximate safe maximum height or depth of embankments or cuttings, and in connection with this the approximate safe maximum load upon different earths, considered as either natural ground (for foundation) or deposited earth as it occurs in embankments.

First, the safe maximum compressive load on natural ground for the purposes of foundations. Tables have been compiled for the approximate safe maximum load in tons per square foot for different earths upon which earthworks are generally built. The following is copied from a set of these tables, showing the compressive strength of the different foundations:

| | | | | | |
|---|---|---|---|---|---|
| (1) | Bog, morass, marshland, etc. - - | 0 to 0.20 | tons | per square | foot. |
| (2) | Alluvial earth, loam and loamy earths - | 0.35 to 1.50 | " | " | " |
| (3) | Damp clay - - - - - - - | 1.50 to 2.00 | " | " | " |
| (4) | Intermixed beds of different sound clays - | 3.00 | " | " | " |
| (5) | Solid clay mixed with fine sand - - | 4.00 | " | " | " |
| (6) | Solid blue clay, marl, boulder gravel, etc. - | 5.00 to 8.00 | " | " | " |
| (7) | Ordinary superficial sand beds - - | 2.50 to 4.00 | " | " | " |
| (8) | Compact-gravel - - - - - - | 7.00 to 9.00 | " | " | " |

In foundations, etc., *rock* is not usually loaded with a greater weight than from 8 to 20 tons per square foot. Reference to authorities on the resistance of rocks to different stresses will give the safe load per square foot, but even upon rock in its natural location this should not exceed one-tenth of the maximum tabulated load.

In the construction of cuttings there is scarcely any limit to the depth, except a due regard to economy, as long as the slopes are sufficiently flat and drainage is properly effected. It is generally found in a long cutting, when it is deeper than 60 feet, that it is cheaper to tunnel, *i.e.*, in the case of ordinary soil. For embankments, however, the load upon the ground and the deposited material restricts the height in a degree, or, on the other hand, necessitates the base being gradually spread out. Hence the consideration of the height of the embankment resolves into two separate problems, viz., the limit to which the embankment may be deposited; and, secondly, the safe load that the earth of which the embankment is composed will sustain. For the solution of the first of these, we have the following:

$$H = \frac{S}{W}$$

where $S$ = Safe load in tons per square foot upon *natural* ground.
$H$ = The theoretical limiting height in feet of embankment.
$W$ = Weight in tons per cubic foot of deposited earth.
$S$ and $W$ being found in tables.

For the solution of the latter part of the problem, it is well to remember that:

Excavated earth cannot be restored in bulk to its original condition. Loam and light earth shrink as much as 12%, while gravel and sand are less.

Earth is usually, soon after deposition, subject to vibration and weather.

Therefore, taking these and other points into consideration, the question is, what deduction is to be made from the tabulated maximum safe load for an unexcavated earth, and to ascertain the safe sustaining power of the *same earth when deposited?* Much depends upon the conditions of the earth and its peculiarities; and for this reason the earths are divided into two classes, viz.: (1) Granular, such as sand, clean gravel, etc., or such as are insoluble in water; and (2) non-granular. A table of approximate safe heights for embankments under these two heads, compiled from different authorities, is given below:

| | | feet. | |
|---|---|---|---|
| GRANULAR EARTHS | Clean gravel | 90 | Approximate safe permanent height. |
| | Sharp compact sand | 80 | |
| | Ordinary loamy sand | 40 to 60 | Good conditions. |
| NON-GRANULAR EARTHS. | Alluvial soil from river bed | 5 to 8 | |
| | Ordinary alluvial soil | 15 to 30 | |
| | Boulder clay | 25 to 30 | |
| | Damp clay soil | 25 to 30 | |

In cuttings the depth might safely be increased by 25% over the above. It is seldom economical to make an embankment more than 70 or 80 feet high except for short lengths where the foundations for a bridge are known to be of a treacherous character, or where there are deep cuttings adjacent which cannot be avoided, for then it becomes a question of carefully constructing the embankment merely as an immense spoil bank.

We will now consider the different systems of deposition of an embankment and the circumstances in connection with it. One of the chief objects in the deposition of an embankment is to make it homogeneous, and prevent, as much as possible, different kinds of earth being tipped in different states of weather. Careless and intermittent tipping conducted in wet and dry weather, and with several qualities of earth, is a frequent source of slips or subsidences later on. It may appear very easy to decree, from slight acquaintance with the location of any piece of work, arbitrary rules as to the quality of material, manner of handling, and so on ; but the exigencies of such, upon the carrying out of the plan, may demand the very opposite procedure. For instance, it may happen that there is no available material for miles about, except, say, sandy clay, with which we require to build an embankment of considerable height. This, under ordinary circumstances, would not be thought of, but it has sometimes to be done, and *will* have to be done. Care should be taken that the earth deposited be, throughout the embankment, the same or nearly the same ; and when in a cutting from which is being taken material for an embankment a seam of unstable soil occurs, it should not be tipped into the embankment, but run into a spoil bank. It often happens that it is cheaper to obtain earth for small embankments from what are called side-cuttings (forming a sort of borrow pit) rather than from regular cuttings, especially if land be plentiful. These side-cuttings are cuttings parallel to the foot of the slope a short distance from it, and thus in this way they form a good drainage system. However, this will be mentioned further on. Another point to be observed in deposition is that the material be as much as possible in particles of uniform size, thereby increasing cohesion.

The first operation for the deposition of an embankment is the preparation of the ground on which it is to rest. Solid mounds or hillocks, etc., must be left, but vegetable or brush growth should be removed. In particular cases, it is well to plough the ground in places to offer a rough surface, and this especially for embankments on slightly sidelong or hillside ground. In steeper sidelong ground, however, it is better to trench or cut the surface into steps, as it were, and by this means offer a rough foundation to prevent movement, as well as a system of partial drains.

We now come to the drainage of the natural ground on which the embankment is to rest, so that the water percolating through the embankment may be drawn off. This may be accomplished by a system of parallel rough stone drains running transverse to the embankment at a distance of, say, 18 feet apart, with several longitudinal drains the entire length of the embankment.

One frequent cause of subsidences in embankments after being completed is the deposition of material in all states of humidity, from dry and dusty soil to wet and saturated soil. This has a tendency to induce stratification, as it were, in the work, and consequently an unequal settlement. All saturated earth taken from a cutting should, if practicable, be run to spoil. However, this is not always possible, for it may appear in small patches, and it would not pay to shovel it into wagons for the purpose. But if it occurs in considerable quantity, the above rule should be followed. No mould, mud, soft pasty earth, frozen earth or snow, should, under the best construction, be put into an embankment.

We now come to a most important part of the subject, viz., the system of tipping. Most embankments (take, for instance, railroad embankments) are formed in masses of not more than, say, 3 cubic yards at most, according to the capacity of the wagons. From this we see that however short may be the "lead" (*i.e.*, the distance from the excavation to the embankment), this 3 cubic yards of earth will be greatly disturbed, both by the jolting movement of the conveyance, and chiefly by the act of tipping down the embankment head. The greater the height of the embankment, the greater will be this effect. No solid lumps of considerable size should be allowed to be tipped with shovelled material of the same kind, for then these lumps will roll down the slope, perhaps lodging on the way, and forming (when in large numbers) a mass which is not strictly homogeneous, and hence not in accordance with good construction. The lumps can be easily broken up. In the case of granular earths, as sand and gravel, the height of the tip would not need so much attention, as the particles would fall into repose equally, and would not be affected much by water. It is generally found that it is best to erect the embankment to the full formation width, because it may be that the earth afterwards applied would differ in character from that originally deposited; also the original would have weathered for a certain length of time, and the new material would not be stable. If in wide embankments there should be a number of tipping heads or roads; they should proceed equally, in order that the material be the same, and equally exposed. In wet weather, or when the soil is treacherous (as clay, for instance), it is found better to diminish the height from which the material is tipped, and build the embankment in several layers or courses, depositing each layer to its respective necessary width, care being taken that the lower layer is sufficiently wide to receive the top layer; the top of the lower layer should be made slightly concave.

It often happens that slips occur when the central portion of an embankment is built of one material and the slopes of a different, the latter slipping or sliding on the former. No side tipping should be allowed in a new embankment, and, if possible, additions to the slope should not be made, although it may be necessary in trimming up the slope, but this should be done by the bank-head men as the earth is deposited, when the slope should be made as even as possible to prevent lodgment of water, etc.

The most critical and tedious part of the construction of an embankment is the closing up of the earthwork and making a firm joint between the surfaces which are to be closed, wherever they may be. In small embankments the tipping is usually done from one end, and thus the work is built, the junction being made on the opposite side and with the natural surface, which should be prepared to receive the deposited earth in the same way as for foundations for the embankment. However, the question of tipping from one or both sides depends altogether upon the cutting or place where the material is being obtained. In large embankments it is preferable to tip from both sides and close at the centre, as the joint can be made more homogeneous than at the end. It is necessary therefore that the earth between the two tip heads be of the same character and condition as nearly as possible. It will generally be found that it will require more material to close two high tip heads than would appear from the computation of the earthwork.

We will now turn our attention to the drainage of earthwork. In the first place, to consider the systems of draining the *beds* of the different works, viz.:

(1) Cuttings. The bed of the cutting is of course composed of the natural ground, and other than side ditches at the foot of the side slopes requires no special drainage except that necessarily imposed by the highway proper. These side drains are built quite large, to receive all the water from the slopes and conduct it beyond the cutting. They should be at least two feet wide and one foot deep, and should be built without sharp bends, by which the slope, etc., are eroded. In good firm soils it is hardly necessary to stone these ditches, but in sandy and loose soils it is, for the wash of the water will erode the slope and carry away considerable silt. To prevent this, the ditches can be filled with broken stone, or, better still, covered or pipe drains can be substituted.

(2) Embankments. This has been slightly mentioned before. At the base of the slope a deep ditch might be cut as near the fence as convenient. For ordinary soils this is sufficient; but where the earth retains moisture easily, it becomes necessary to drain the seat of the embankment. One way is to construct (before depositing any material) trenches at intervals, at right angles or obliquely to the centre line, filled with stone or gravel. A cheaper method is to excavate the foundation so that the centre is several feet below the sides, a small trench provided with suitable inclinations, and

filled with broken stone, etc., running along the centre line to the nearest culvert.

In regard to culverts, they are usually placed at the deepest portion of an embankment to conduct the stream (if any) beneath. They should be large enough to admit a man, and are usually, of a considerable size, and built of masonry in the form of an arch, or heavy timbers. In the former, it is well to have a coat of cement on the inside to aid the quick passage of the water, and in all culverts this same idea should be followed, so as to reduce the friction as much as possible. Smaller culverts may be built of brick, concrete, or rubble concrete, preferably in the form of an arch. Culverts should have provision at the ends, especially the upper end, to guard against the wash of the stream. This is a most important point, for if the toe of the embankment be exposed to the current, it is apt to be disturbed by undermining, etc. This is best prevented by building splay wing walls, by which the water is kept from the toe of the slope and guided into the culvert. Besides this, it is good practice to build masonry retaining walls at the base of the slope in the vicinity of the stream, to guard against the results of the stream "backing up" at flood time; this, however, should be seen to when building the culvert itself that it should be large enough to accommodate all the water which could come down.

We will now consider the drainage and protection of the slopes of earthworks. There are many ways of doing this. With respect to cuttings, the chief consideration is "to gently extract and conduct the water so as to avoid any accumulation on or beneath the original surface which would affect the slopes." The main point in either a cutting or embankment is to keep it in a uniform state, so as to facilitate equal settlement. This is best effected by preventing any water from collecting in depressions in the slopes; for, as water is the chief cause of slips, it must not be allowed to accumulate in such a way as to saturate to excess any particular portion of the slope, and thus make a slip possible. One frequent cause of this accumulation arises from the position of the strata outcropping in the slopes of a cutting. Wherever a permeable stratum overlies an impermeable in a section of tilted or inclined strata, an increased flow of water may be expected. In soils of a sandy or loamy nature percolation of water must be provided for, for there will be a large quantity of the percolated rainfall in the surrounding land, which will manifest itself on the slopes of the cutting. In clay soils this percolated water usually appears in fissures and crevices, whilst in soils of a mixed nature springs are the most troublesome. In cuttings, the surface water from above must be drained as much as possible away from the slope. This is done by building catchwater drains at the top of the slope before the excavation of the cut is commenced. These drains should be made as impermeable as possible; for if they are permeable, it must be remembered that they are agents in localizing the flow of the water, and it would perhaps be better if they were omitted altogether. These catchwater drains, if built, should be near the fence, have a considerable inclination, and should be connected with the regular surface drains down the face of the slope. All field drains, etc., should be conducted into these catchwater drains. A spoil bank should never be deposited near the top of a slope of a cut, since it imposes an extra weight and localizes water. The slopes proper can be drained by wells, closed or open channels, pipes, tile drains, or catchwaters. To describe minutely each of these is not in place here, but in a general way their necessity for different purposes may be regarded. Rock and solid impermeable earth may require only to be surface drained, which may be easily done by open channels down the slope, either directly or at an inclination. But in all treacherous material, such as sandy loam, clayey soils, and mixed soils, deep draining is necessary. In sandy and mixed earths, extra precautions, besides the usual side drains, and top drains, may be to sink, on the slope, wells filled with broken stone, etc., having drains leading from them. Tile drains might also be used. In clay soils, especially in embankments, deep draining is necessary, and the drains, which need not be large, might be made of rubble stone. In embankments, the drains should be built as the material is deposited, and should be at short intervals throughout the mass, and emptying into the surface drains of the slope. It is a question whether the drains on the slopes should be perpendicular to the side drains or inclined to them. If the soil is likely to slide, or is treacherous, it is perhaps better to have them run directly down, because otherwise the cohesion will be destroyed. It is generally found that "filled in" trenches are successful, and they are certainly cheaper. They may be made of stone, set in gravel, ashes, or such material, and should be at least 3 feet wide and 1½ feet deep and should have careful and deep connection with the side drains at the foot of the slope. It does not always follow that the more of these drains there are on a slope the better will be the drainage, for a large number of them may tend to weaken the slope.

The toe of a slope is its weakest point, and should be protected in preference to everything else. There are several ways of doing this. First, and simplest, for embankments only, cut a trench of considerable size in the natural surface, and so placed as to allow the slope of the deposited material to abut against it. Second, an impervious retaining wall, say, of masonry, with a pervious backing of gravel or sand, may be built, allowing the slope to abut against it. This masonry retaining wall should have a deep foundation, and be of such dimensions as will be required by the weight imposed and the inclination. At intervals of at least every ten or twelve feet a channel through the base of the wall should be left, so as to allow the water which comes down through the porous backing to find its way to the side drains. These channels, called "weep-holes," need not be large. The height of the retaining wall will of course be governed by existing circumstances, but in most cases need not be more than, say, five feet. One trouble with these walls in our country is that, on account of being constantly exposed to moisture, frost will cause them to bulge out and weaken the slope. The only way to prevent it seems to be to secure thorough and rapid drainage, and shore the wall with timber. These walls are found most useful in loose soil, such as sand, or gravelly sand, but in cohesive soil, as clay, etc., they are hardly necessary if good slope protection and drainage is maintained.

Third system of protecting toe: Build a pervious wall or "counterfort" of gravel, rubble, or other firm material. This is found useful in loamy earth, or soil of a semi-cohesive nature, and even clay. The gravel, etc., should be well rammed in shallow layers, and the whole should have a foundation considerably beneath the base of the formation. A good example of well-drained cuttings is found on the G.T.R. where it passes beneath the Welland Canal. There are several miles of cuttings having inclined stone drains running diagonally across the slopes, heavy stone retaining walls, etc., etc.

As to the protection of a slope, the most common method is by vegetation. This vegetation should be compact, uniform, and remain throughout the year. Grass sown on the incline is found to be the best for this, for its roots bind the earth so well together. The less cohesive the soil is, the deeper the roots should be; but for clay soils the roots need not be so deep as close together to prevent water furrowing the slope. There are some soils, however, on which it is impossible to get grass or other such vegetation to grow. Of these, sand is the most troublesome. It is found very frequently in moist sand that willows will grow well, and these with their large roots are very useful. It has been found that quite often slips are prevented by planting low saplings or shrubs on a slope; but care should be taken that the roots do not strain the ground by force of wind or other cause

In our country, snow is a frequent cause of trouble in cuttings and hill-sides. Many preventive measures have been adopted, of which some might be mentioned:

(1) Building snow sheds.

(2) Building permanent or portable screens.

(3) Increasing the width of formation.

First; snow sheds are of course expensive, but are the most effectual. They are used on the C.P.R. and the Intercolonial to a great extent. They must necessarily be built very strongly to resist snow and ice slides.

Second; screens, such as earth mounds, hedges, fences, etc., are effective, and comparatively economical. Close trees, such as pine, spruce, or cedar, planted some distance back of the cess or crown of the slope catch the snow considerably, but lessen the effect of the wind on the slopes for drying purposes in the wet season. A trench should be built on the lee side of the trees to carry away the snow water.

Third, the increase of the formation or roadway is also effective, as it gives more surface and allows more room for the snow plough and the section men to work. In such places the side drains should be very deep.

# THE COMPUTATION OF EARTHWORK AND OVERHAUL BY MEANS OF DIAGRAMS.

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By Edward F. Ball.

*Mr. President and Gentlemen,*—I greatly regret that this paper will not partake of that "practical" nature descriptive of constructive details which is so keenly appreciated by engineers. Although not "practical" in the usually accepted meaning of the term, the subject will be found of great practical utility to those who have occasion to make extensive computations of earthwork and overhaul, especially on railway work.

The first part of this paper, that relating to earthwork, is extracted from that admirable book entitled "Computation from Diagrams of Railway Earthwork," by A. M. Wellington. My excuse for occupying your time with a subject treated exhaustively in the work referred to is that this book is of comparatively recent publication (1888), and is not nearly so widely known as it deserves to be.

The method described in the second part of this paper relating to overhaul is believed to be different from anything published on the subject, and combines the two desirable features of accuracy and readiness of application. The invention of this method is claimed by a Dutch engineer on the Lehigh Valley Railway, from whom the writer obtained a description delivered in a language in which every "w" was converted into a "v"; "th" into "d"; "yes" into "yah," or more frequently "yap," etc.; but as language was given to man to *conceal* his thoughts, why attempt to criticise the shell that envelops and hides the kernel?

The writer wishes to put in a small claim for distinction for modifying the method of calculation so as to secure the greatest possible accuracy, but is not entitled to any further credit.

## COMPUTATION OF EARTHWORK.

The old method of computing solidities by means of end areas is very laborious, and unless the cross-sections are taken frequently enough to ensure only a small difference between two consecutive end areas is widely erroneous, the error being in favor of the contractor, *i.e.*, the calculated volumes being in excess of the actual volumes. The application of the prismoidal formula in this method is so lengthy and tedious as to be entirely out of the question.

The usual method of calculating the areas of "three-level" section is as follows:

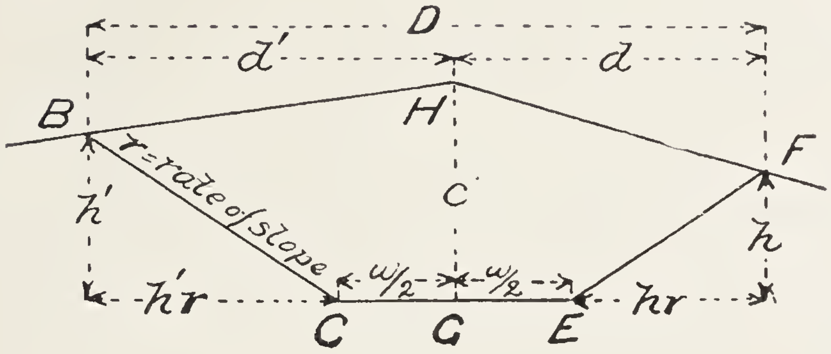


FIG. I.

$$2 \text{ area of } \Delta\ BCG = \frac{w}{2} \times h'$$

$$2 \quad `` \quad `` \quad ``\ FEG = \frac{w}{2} \times b$$

$$2 \quad `` \quad `` \quad ``\ BHG = cd'$$

$$2 \quad `` \quad `` \quad ``\ FHG = cd$$

$$\therefore \ 2 \text{ area of whole section} = c\,(d+d') + \frac{w}{2}\,(h+h')$$

or,

$$A = \frac{c\,(d+d') + \frac{w}{2}\,(h+h')}{2} \qquad \text{Eq. (1)}$$

This equation contains four variables, $A$, $c$, $(d+d')$ and $(h+h')$, but $d$ and $h$ are functions of each other, for $d$ is always equal to $hr + \frac{w}{2}$, and $h = \frac{d - \frac{w}{2}}{r}$

Substituting this value of $h$ in Eq. (1),

$$A = \frac{(d+d')}{2}\,c + \frac{\left\{\frac{d - \frac{w}{2}}{r} + \frac{d' - \frac{w}{2}}{r}\right\}}{4}\,w, \text{ which simplifies to}$$

$$A = (d+d')\,\frac{c}{2} + (d+d')\,\frac{w}{4r} - \frac{w^2}{4r} \qquad \text{or letting } (d+d') = D$$

$$A = \left(\frac{c}{2} + \frac{w}{4r}\right) D - \frac{w^2}{4r} \qquad \text{Eq. (2)}$$

In the foregoing equations the lineal dimensions are always expressed in feet, but the solidity $S$ is required in cubic yards.

Letting $S$ = the end-area solidity of a solid of the usual length, 100 feet,

$$S = \frac{A + A'}{2} \times \frac{100}{27} = (A + A')\,\frac{100}{54}$$

In the formula

$$S = (A + A') \times \frac{100}{54} \text{ or } S = (A + A') \times \frac{50}{27}$$

it is of course apparent that

$$S = \left(A \times \frac{50}{27}\right) + \left(A' \times \frac{50}{27}\right)$$

or, to express these figures in words, the total end-area solidity of a prism

100 feet long with end-areas $A$ and $A'$ = the solidity of a prism 50 feet long of end-area $A$ plus the solidity of a prism 50 feet long of end-area $A'$.

Let $s = A \times \frac{100}{54}$, or the solidity of a prism of end-area $A$ and length 50 feet:

$$\therefore \quad s = \left\{ \left( \frac{c}{2} + \frac{w}{4r} \right) D - \frac{w^2}{4r} \right\} \times \frac{100}{54} = \frac{50}{54} \left( c + \frac{w}{2r} \right) D - \frac{25w^2}{54r}$$

In this equation there are but three variables: $c$ the centre height, $D$ the width between slope stakes, and $s$ the corresponding solidity in cubic yards for a length of 50 feet. If we construct diagrams for values of $c$, taking ordinates parallel with the axis of $x$ to represent values of $D$, and ordinates parallel with the axis of $y$ to represent values of $s$, we will have a number of radial lines as shown in plate 1.

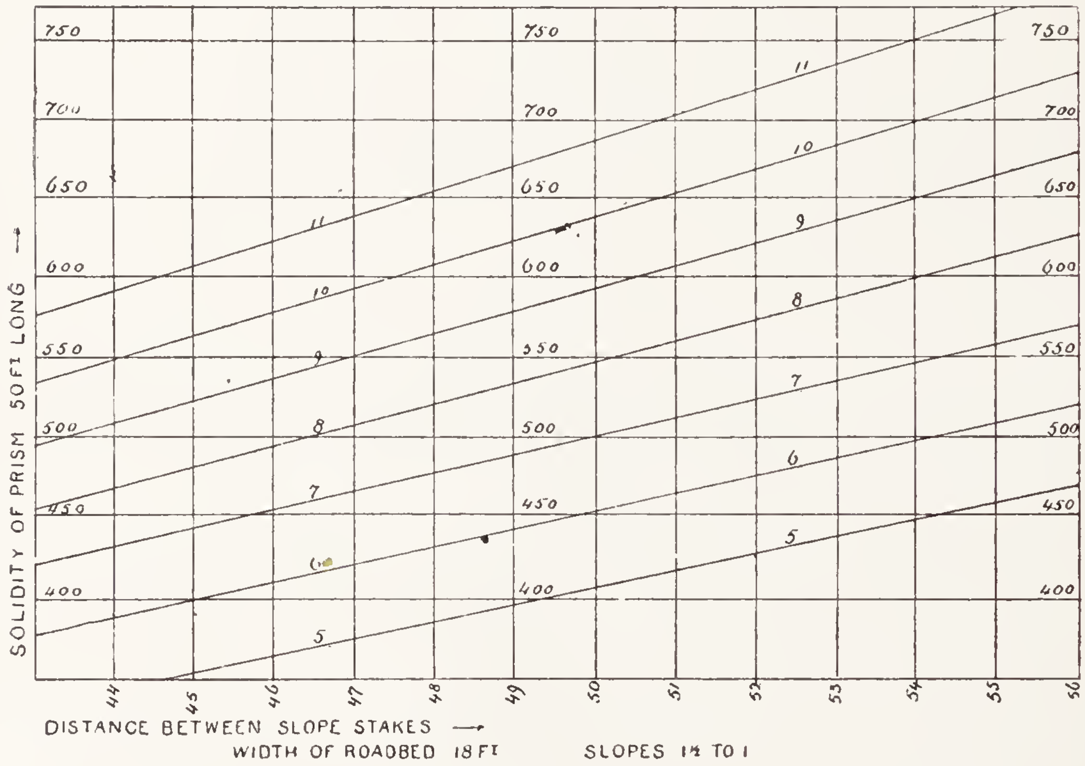


PLATE I

Suppose, now, that we wish to find the solidity of a railway cut 100 feet long, width of roadbed 18 feet, slopes 1½ to 1 foot, distance between slope stakes 48 and 50 feet, depth of centre cuts 10 and 11 feet respectively. Follow up the vertical line corresponding to 48 (plate 1) to the intersection of the diagonal line corresponding to 10; the horizontal line at the intersection represents 611 cubic yards. Similarly with the other section, the solidity is 687 cubic yards. The sum of these = 1298 cubic yards. Should the length of the cut be 30 feet instead of 100, multiply the result by 0.3 = 389 cubic yards.

The diagram shown in plate 1 is not drawn very accurately, so that the results obtained from it do not quite agree with the above.

Accompanying Mr. Wellington's book are diagrams for different widths of roadbed and slopes, and also a number of others for various uses. By the use of these the tedious labor of computing areas, which, by the method shown in Eq. (2) is more than one-half the total work of computation, is entirely avoided. In some other methods the saving is from two-thirds to four-fifths.

Some engineers will work out solidities to the decimal part of a yard, but this is ridiculous nonsense, for no cross sectioning is done so accurately as that. At first sight, it would appear that the locus of $c$ in the equation

$$s = \frac{50}{54}\left(c + \frac{w}{2r}\right) D - \frac{25w^2}{54r}$$

would be a curve, but, in reality, it is a straight line, for the expression $\frac{25w^2}{54r}$ is constant for any one diagram, and the equation may be written $s = \frac{50}{54}\left(c + \frac{w}{2r}\right) D - c''$, which is of the first degree and represents a straight line.

Having examined a very rapid and accurate method for computing end-area solidities, let us investigate one for determining them precisely by means of the prismoidal formula, which is

$$S = \frac{A + A' + 4M}{6} l$$

in which $A$ and $A'$ are the two end areas, $M$ the area of a section midway between (which is *not* the mean of $A$ and $A'$), and $l$ the length of the solid. We cannot reduce this to a simple formula with three variables as in the previous case, but we can obtain a ready method for finding the correction to be subtracted from the result obtained by the end-area method. Without going through the various deductions, I will simply state that diagrams are constructed from which the correction may be found having given the differences $c - c'$ and $D - D'$, in which $c$ and $c'$ are the centre heights at the ends of the solids, and $D$ and $D'$ the corresponding distances between slope stakes.

## OVERHAUL.

Let us suppose that the limit of free haul is 1000 feet, and the prices for overhaul are 1 cent per cubic yard per 100 feet up to 2000 feet, and ½ cent per cubic yard per 100 feet beyond 2000 feet. It first becomes necessary to find the points at which overhaul begins, *i.e.*, how far beyond the grade point the material from the cut would build the embankment without exceeding the limit of free haul—1000 feet, and also the limit of the 1 cent rate where the haul reaches 2000 feet, after which we find the average distance that the material was hauled in the 1 cent rate and also in the ½ cent rate. This presents the appearance of a very easy problem, but its *accurate* solution requires considerable care.

Commencing at the grade point *G* (see profile), add up the total number of cubic yards of excavation and embankment to each station as follows :

EXCAVATION.

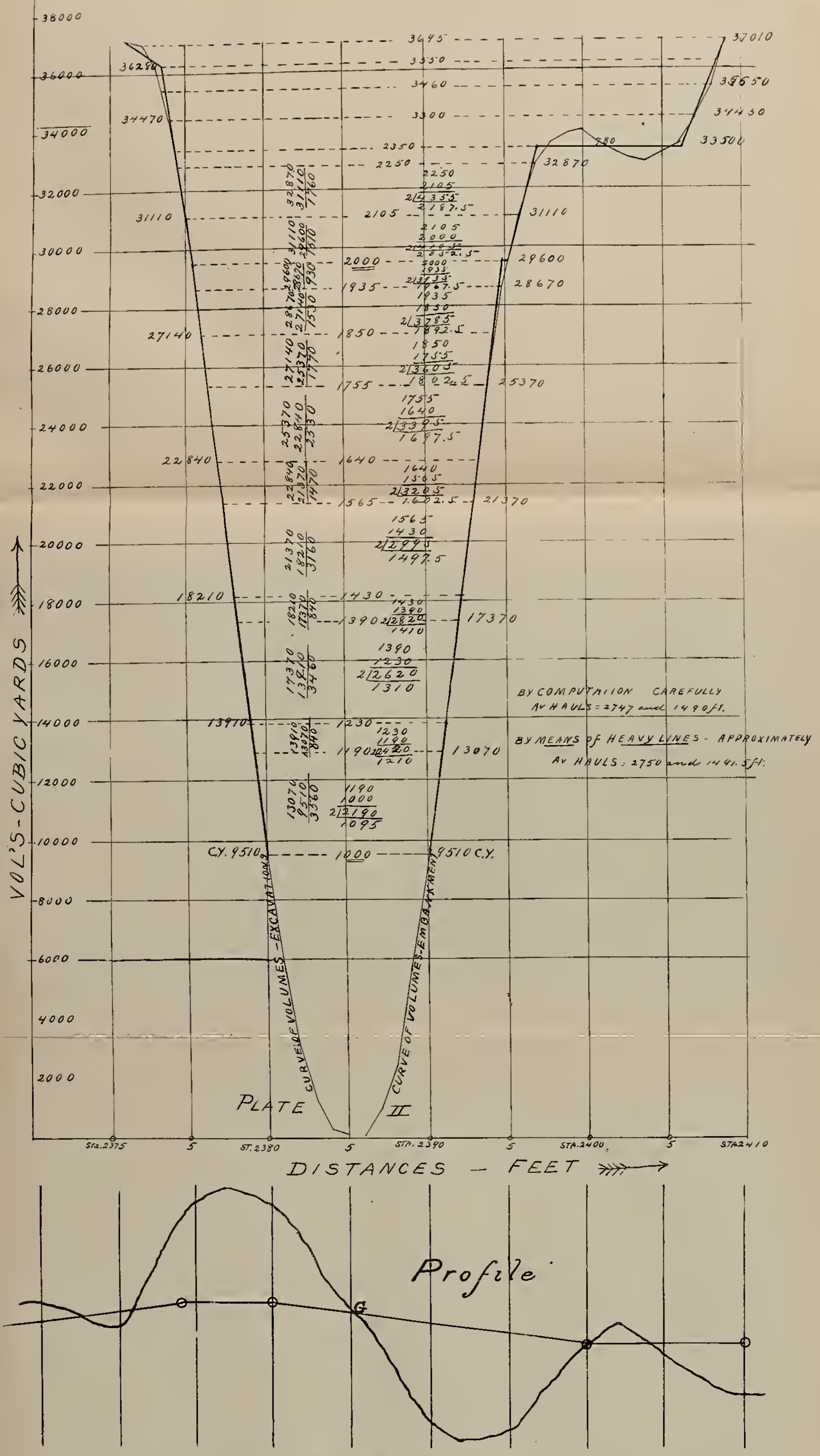
From grade point to station 2385 = 100 cubic yards.
" " " " 2384 = 330 " "
" " " " 2383 = 1330 " "
etc., etc. etc., etc.

EMBANKMENT.

From grade point to station 2386 = 70 cubic yards.
" " " " 2387 = 870 " "
" " " " 2388 = 2570 " "
etc., etc. etc., etc.

These results should be tabulated in the following form :

| EXCAVATION. + | | | EMBANKMENT. − | | |
|---|---|---|---|---|---|
| Station. | Quantity C. Y. | Total Quantity from G C. Y. | Station. | Quantity C. Y. | Total Quantity from G C. Y. |
| "G" | | | "G" | | |
| | + 100 | | | − 70 | |
| 2385 | | + 100 | 2386 | | − 70 |
| | 330 | | | 800 | |
| 84 | | 330 | 87 | | 870 |
| | 1000 | | | 1700 | |
| 83 | | 1330 | 88 | | 2570 |
| | 1810 | | | 3000 | |
| 82 | | 3140 | 89 | | 5570 |
| | 2800 | | | 3500 | |
| 81 | | 5940 | 2390 | | 9070 |
| | 3670 | | | 4000 | |
| 2280 | | 9610 | 91 | | 13070 |
| | 4300 | | | 4300 | |
| 79 | | 13910 | 92 | | 17370 |
| | 4300 | | | 4000 | |
| 78 | | 18210 | 93 | | 21370 |
| | 4630 | | | 4000 | |
| 77 | | 22840 | 94 | | 25370 |
| | 4300 | | | 3300 | |
| 76 | | 27140 | 95 | | 28670 |
| | 3970 | | | 2500 | |
| 75 | | 31110 | 96 | | 31170 |
| | 3360 | | | 1700 | |
| 74 | | 34470 | 97 | | 32870 |
| | 1810 | | | 800 | |
| 73 | | 36280 | 98 | | 33670 |
| | 820 | | | 200 | |
| 72 | | 37100 | 99 | | 33870 |
| | 80 | | | − 80 | |
| 71 | | 37180 | 2400 | | 33950 |
| | | | | +230 | |
| 2370 | | | 1 | | 33720 |
| | | | | 500 | |
| | | | 2 | | 33220 |
| | | | | 100 | |
| | | | 3 | | 33120 |
| | | | | +100 | |
| | | | 4 | | 33020 |
| | | | | − 200 | |
| | | | 5 | | 33220 |
| | | | | 450 | |
| | | | 6 | | 33670 |
| | | | | 780 | |
| | | | 7 | | 34450 |
| | | | | 1100 | |
| | | | 8 | | 35550 |
| | | | | 1460 | |
| | | | 9 | | 37010 |
| | | | 2410 | | |



ERRATA.—For station 2375 read station 2370, and on curve of volumes for embankments for 31110 read 31170.
On these curves the heavy and light lines so nearly correspond that it is impossible to show them in their exact position in a drawing of this size.

Now take a sheet of cross-section paper and from the preceding table plot curves representing volumes for excavation and embankment, as shown in plate II; distances along $ox$ representing lineal feet and along $oy$, cubic yards. The vertical lines are numbered from 2370 to 2410 to correspond with the chainage, as shown on the profile. Wherever a point is established on either curve make a small circle, and draw a horizontal line across to the other curve. Scale the length of this line and note the result, as shown in plate II. From station 2400 to 2404 a small cut will be noticed, but this is treated as a negative fill, and in adding up the volumes in embankments this is subtracted and causes the curve to drop at $AB$, plate II.

Now take a scale, and, keeping it always parallel with the axis of $x$, find at what points the two curves are 1000 and 2000 feet apart. Thus it is ascertained that the limit of free haul is at station 2390 + 10, and the limit of the 1 cent rate at station 2395 + 30.

Let us compare the hauling of a cubic yard of earth 1 foot horizontally to the raising of a pound weight 1 foot vertically. This is called a foot pound of work, and we may coin a similar expression, a "foot yard" of work, which means the work done in hauling a cubic yard of earth a horizontal distance of 1 foot. Suppose, now, we have a very small cut of, say, 12 cubic yards, and that the first 2 yards were hauled 10 feet, the second 2 yards 11 feet, the third 2 yards 12 feet, etc., and the last 2 yards 15 feet. The total amount of work done:

$$\begin{aligned} 2 \times 10 &= 20 \text{ foot yards.} \\ 2 \times 11 &= 22 \quad " \quad " \\ 2 \times 12 &= 24 \quad " \quad " \\ 2 \times 13 &= 26 \quad " \quad " \\ 2 \times 14 &= 28 \quad " \quad " \\ 2 \times 15 &= \underline{30} \quad " \quad " \\ & \quad 150 \text{ foot yards.} \end{aligned}$$

We may simplify the above computation by dividing the 12 cubic yards into 2 groups of 6, instead of 6 groups of 2, thus:

$$\begin{aligned} 6 \times 11 &= 66 \text{ foot yards.} \\ 6 \times 14 &= \underline{84} \quad " \quad " \\ & \quad 150 \text{ foot yards.} \end{aligned}$$

Thus in actual work we may divide the total volume into smaller ones of such a size that we can determine very closely the average haul for each yard in that particular volume. By consulting the diagram, plate II, we find that from 9510 to 13070 cubic yards the average haul is $\frac{1000 + 1190}{2}$ = 1095 feet; therefore the amount of work done = (13070 − 9510 cubic yards) × 1095 feet = 3560 × 1095 = 3898200 foot yards. Similarly, between 13070 and 13910 the amount of work done $= 840 \times \frac{1230 + 1190}{2}$ $= 840 \times 1210 = 1016400$ foot yards, and so on up to the 2000-foot haul. By working out all these multiplications as in the table, we find that the total amount of work done in the 1 cent rate = 29928250 foot yards. Now the total number of cubic yards moved between the 1000 and 2000-foot limit $= 29600 - 9510 = 20090$ cubic yards, and the total amount of work done, or, in other words, the product of the number of yards multiplied by the distance hauled = 29928250; therefore the *average haul* is obtained by dividing this product by the number of cubic yards $= \frac{29928200}{20090} = 1490$ feet, which is the desired information.

| | VOLS. | DIST. | PRODUCT. | | VOLS. | DIST. | PRODUCT. |
|---|---|---|---|---|---|---|---|
| HALF CENT RATE. | 730 | 3623 | 2644790 | ONE CENT RATE. | 930 | 1968 | 1830240 |
| | 730 | 3505 | 2558650 | | 1530 | 1892 | 2894760 |
| | 1080 | 3380 | 3650400 | | 1770 | 1803 | 3191310 |
| | 970 | 3215 | 3118550 | | 2530 | 1697 | 4293410 |
| | 630 | 2300 | 1449000 | | 1470 | 1603 | 2356410 |
| | 1760 | 2177 | 3831520 | | 3160 | 1497 | 4730520 |
| | 1510 | 2053 | 3100030 | | 840 | 1410 | 1184400 |
| | | | | | 3460 | 1310 | 4532600 |
| | | | | | 840 | 1210 | 1016400 |
| | 7410 | | 20352940 | | 3560 | 1095 | 3898200 |
| | | | | | 20090 | | 29928250 |

Now, by looking at the table, it will be seen that the sum of all the products really represents the area between the two curves and the 1000-foot and 2000-foot line of haul. This may be obtained much more readily and with sufficient accuracy by drawing heavy lines containing an equal area, as shown on diagram, and computing the area of the enclosed figure. By this method the average haul is found to be 1491.5 feet, a difference of only 1½ feet. This is the great advantage of this particular method of computing overhaul; for after the diagram is plotted and the heavy lines drawn, the computation is very simple and quite accurate. Should the utmost precision be demanded, the method before described will give it.

In the example given, the average haul in the 1 cent rate is found to be 1490 feet, and in the ½ cent rate 2747 feet. It must not be understood that the contractor is paid 1 cent per yard per 100 feet for 20090 cubic yards hauled 1490 feet, as the first 1000 feet is free haul. The amount due on the 1 cent rate would therefore be 20090 cubic yards × $4\frac{9}{10}$ cents = $983.78. Similarly, the ½ rate amounts to

7410 cubic yards hauled 1000 feet @ 10 cents per cubic yard.
7410 cubic yards hauled 747 feet @ ½ ($7\frac{47}{100}$) cents,
= 7410 cubic yards × 10.3735 cents = $1017.76

# WATERWORKS SYSTEMS OF AMHERSTBURG AND ESSEX.

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By A. T. Laing.

*Gentlemen*,—It was the lot of the writer to be engaged as assistant engineer on the above work. In view, therefore, of the fact, I concluded to lay before you the methods by which the work was conducted, and to relate a few facts, which, I hope, may prove interesting and instructive to you.

The great number of advantages to be derived from an efficient system of waterworks is too well known to you to necessitate my occupying space with that part of the subject. Our engineering journals contain a great deal of useful information on waterworks; but as most of the matter pertaining to this subject deals very largely with the theory and the construction of extensive systems, I shall therefore confine my remarks to the practical part of the subject, and its application to such systems as we have before us.

When a corporation contemplates establishing a system of waterworks, it is their first duty to consider both quality and quantity of water supply, and the financial condition of the town. If the project be deemed at all practicable, an engineer is engaged to investigate the matter and give an estimate of the probable cost. The council then submits a by-law for this amount for the approval of the ratepayers, by the passing of which they are warranted in proceeding with the work. A competent man is engaged as consulting engineer, whose duty it is to prepare all plans and specifications necessary for the construction of the work, and to inspect it during erection. Tenders are then advertised for, and the work may be let either in bulk or in sections, as may be deemed most advisable.

Amherstburg is a small town very beautifully situated on the watery highway of Canadian and American commerce, viz., the mouth of the Detroit River. It was named after General Amherst, and was the scene of several engagements during the war of 1812, in commemoration of which event the old fort and blockhouses still stand. It has also been alleged that it was at this place that the old hero, "Uncle Tom," first entered "the land of the free."

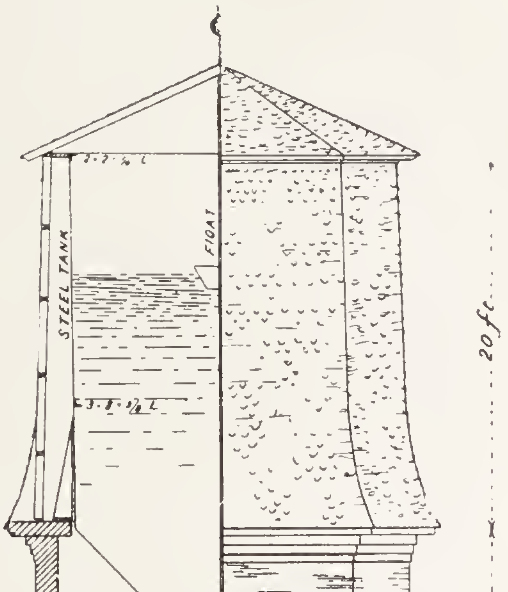
The agitation for waterworks began in the fall of 1890. Early in 1891 the by-law was passed, upon which Mr. John Galt, C.E., Toronto, was engaged as consulting engineer. The plans were prepared at once, and operations were commenced about the 1st of May, 1891.

With a town so situated, no trouble could arise from water supply. Near the river a vertical shaft was sunk, 10 feet in diameter, 15 feet deep, lined with brick laid in cement. Into this the water is conducted by gravity through a 12-inch conduit pipe, extending 200 feet into the river. In order that this pipe may adjust itself to any unevenness in the bed of the river, it is made with the usual ball and socket flexible joint. Joints of this kind are made on the same principle as the joint for a compass-box on the head of a jacob-staff. The bell is bored out, leaving a smooth concave surface inside. The spigot which enters this is provided with a notch, which serves to hold the lead in place, thus making a close joint which may safely move through an angle of 30 or 40 degrees without breaking or leaking. This greatly facilitates the operation of laying the pipe under water; for each joint may be made above water and the pipe lowered afterwards. This part of the work was conducted in the following manner: A scow was brought close to the bank and loaded with pipes, and as each joint was made it was moved out one length, letting the pipe lower like a chain from the rear into the river. This is all that is required with this part of the work, and, if properly understood, it may be conducted more rapidly than laying pipes in the streets.

The intake for this conduit consists of a 12-inch right-angled bend. The open end is protected with a sieve, and the other end, which is connected with the conduit, is provided with a broad casting, which retains the pipe in an upright position, thus allowing the water to enter at a point about five feet above the bed of the river, and preventing the entrance of sediment. At the end next to the well is placed a gate valve, which may be closed when the well requires cleaning. This pipe is produced downwards to within a few feet of the bottom, so as to act as a syphon, when the portion of the pipe between the well and the river is above the varying water level, and from this well the water is drawn by the pumps through a 10-inch suction pipe.

The pumps are of the compound duplex direct-acting type, having capacity for raising water about 20 feet and delivering at a reliable fire-speed about 800 gallons per minute against a hydraulic pressure of 100 lbs. per square inch, with a steam pressure of 80 lbs. per square inch. The steam for this purpose is furnished by an ordinary boiler, which is fed by a duplex feed-pump. This pump forces the water through a heater, through which the exhaust steam from the large pump passes, thus feeding the boiler with water at a high temperature and saving fuel. The pump and boiler house is built in connection with a very commodious seven-room brick dwelling for the convenience of the man in charge.

From the pumps the water is forced into the system through a 10-inch main, which also is provided with a valve, so that the pressure of the system may be shut off the pumps at any time. Connected with this main, and about 100 feet from the pumping station, stands an elevated storage tank. This tank, which was designed by the engineer, is 16 feet in diameter and 20 feet deep, and is made of steel riveted together in five courses each four feet high. The lower course is $\frac{5}{16}$ inches thick, the next two $\frac{1}{4}$ inches, and the remaining two $\frac{3}{16}$ and $\frac{1}{8}$ inches respectively. This work is stayed with two angle bars riveted all around inside, one at the top 2x2x$\frac{1}{4}$ inches and the other 3x3x$\frac{5}{16}$ inches midway down, as shown in the accompanying cut. The bottom also is of steel $\frac{5}{16}$ inches thick, and is an inverted cone 8 feet deep. The object for making the bottom this shape is to diminish the entry head, thus giving the tank more hydraulic power, to distribute the load evenly over the bearings, and, more particularly, to dispense with the necessity of centre supports, which would be necessary if a flat bottom were used. It also prevents the accumulation of sediment which is the breeder of disease in many reservoirs. The tank is supported on an octagonal shaped stand of substantial masonry; the first 20 feet is built of stone about three feet thick, on top of this is 30 feet of brick work, and in each angle of the octagon is a solid pier three feet by four feet, on which rests the eight bearings of the tank, thus elevating it to a height of 50 feet above the ground. These eight bearings or carrying brackets consist of gusset plates ⅜ inch thick by 7 feet long, with two angle bars 3½x3½x⅜, and a bottom bearing plate 12x15x½ inches, which rests on the piers—all tightly riveted together and to the side of the tank, as shown in the blue prints. Inside is a dish-shaped float of steel with capacity sufficient to displace enough water to overcome the weight of the rod, which is produced through the roof to indicate the water level. At the top of the tank is attached an overflow pipe, and at the bottom a steel down-pipe 2 feet in diameter, tapering to 10 inches at the main.



The whole is neatly and substantially enclosed in framework, which is double lined with matched lumber, and shingled on the outside, thus protecting it from the frost and the extreme heat of summer. In the connection between the tank and the main is a valve which is closed in case of fire, and the pumps act directly on the mains, and any desired pressure may be obtained.

This system of storage commends itself in many ways. Where nature has not provided an elevation, it is cheaper than any other. There is little or no evaporation, and it is much to be preferred to a stand pipe, as it dispenses with the necessity of constant pumping, which is a great consideration in a small town. It is protected from the frost, and is in no danger of being tipped over by the wind when empty; and besides furnishing pressure sufficient for all domestic service, it holds a supply with enough elevation to extinguish any ordinary fire without the use of the pumps.

The extent of piping covers about 20,000 lineal feet; this is provided with valves placed so that any portion may be shut off for repairs. The hydrants are placed about 500 feet apart, and have double hose attachments.

Pipes for this purpose are usually cast in lengths of 12 feet, and should not deviate more than 5 per cent. below the following standard weights:

10 inch pipe, 60 lbs. per lineal foot.
8 " " 45 " " " "
6 " " 30 " " " "
4 " " 20 " " " "

The specials should be of slightly heavier design, and all should be subjected to a hydrostatic pressure of 300 lbs. per square inch, and coated inside and out with tar, laid on hot before leaving the foundry.

The operation of pipe laying is conducted as follows: Trenches are excavated to a depth of 4 feet, into which the pipes are lowered by means of ropes. When the spigot end has been placed in the bell it is followed by a coil of yarn, which is driven to the inner end of the bell to prevent the lead entering the pipe. Around the joint there is placed a rope-like sack of wet clay, leaving a small opening at the top to admit the molten lead. When the space has been filled, the sack is removed and the lead is driven firmly to place by means of caulking tools. The trenches are then filled, having the earth well rammed around and on top of the mains.

At the final test, which was conducted by Mr. Galt in the presence of a large number of citizens, the system was found to give the best of satisfaction. By means of the tank pressure alone water was thrown over the roofs of the highest buildings, and when the pumps were used a very much greater height was attained; and now the citizens of Amherstburg, including even those who opposed the scheme, boast of a cheap and efficient system of waterworks, and claim that in no other town are the requirements better met with.

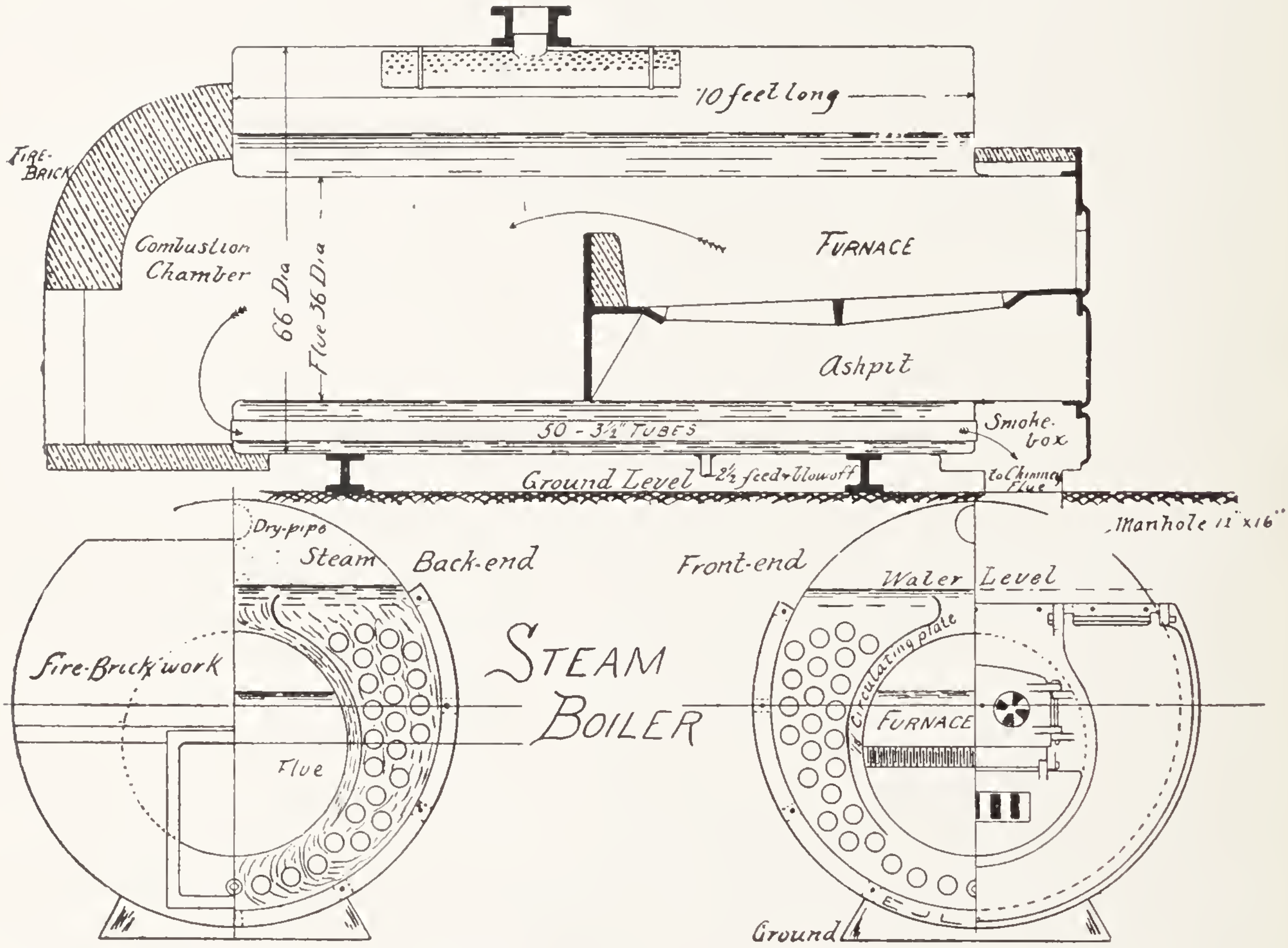
About sixteen miles east of Amherstburg, on the M.C.R.R., and in the centre of a rich agricultural county of the same name, is the enterprising little town of Essex. At this place the scheme met with considerable opposition, but after a few open discussions on the matter the by-law was submitted and carried by a vote of over two to one; upon which Mr. Galt was engaged as engineer, and operations commenced at once.

Here the problem of water supply was a somewhat difficult one. As there is neither lake, river, nor spring to draw from, boring had to be resorted to, and fortunately in a convenient part of the town three good wells, 13 feet apart, were struck at a depth of about 110 feet. These were cased with iron down to the rock, but the water rose only to within about 32 feet of the surface. Now, as no pump can lift water economically more than 25 feet, this involved another difficulty, which was overcome in the following manner: In order to secure a permanent supply of water for the pumps, around these three wells was dug a large well 25 feet in diameter and 50 feet deep, lined throughout with brick one foot thick, laid in Portland cement. The bottom is made of cement concrete 9 inches thick, through which the pipes flow, and the water stands in the well at an average depth of 18 feet. At the side of this well is sunk a vertical elliptical shaft 10x14 inches and 25 feet deep, lined throughout the same as the well; into this the pump is lowered, thus bringing it to within a few feet of the surface of the water. This incurred considerable expense, but the plan met with success, and an abundant supply of good water was obtained.

The pumping engine is similar in capacity and build to the one before described, and access to it is gained by means of a Barnum No. 10 spiral stair. As there is no chance at this depth for draining off the oil drippings and the condensed steam from the cylinders, it is caught in a sump hole at the side of the pump, from which it is thrown out into a drain by means of a steam ejector.

The pump is fed by steam from a horizontal boiler 5½ feet in diameter and 10 feet long, with an internal fire-flue 3 feet in diameter, around and underneath which is placed forty-six 3½-inch flues. The draught passes through the fire-flue to rear of boiler and returns through the tubes to the smoke-box in front, and thence to chimney.

As will be seen from the cut, the furnace front, smoke-box, and combustion chamber in the rear, together with the boiler, are all in one, giving the whole a neat and compact appearance. It is easily fired, has a good draught, and has been found to give the best satisfaction. It was designed by the engineer, and is specially adapted for waterworks service, as it is a quick steam maker. This quality it has from the fact that the source of heat is near the surface of the water in the boiler, where all the hot water tends to collect, thus enabling it to make a considerable steam before all the water has been heated to the point of evaporation. Scaling is prevented by means of circulating plates, which partially envelop the fire-flue a few inches away from it. This plate is open at the bottom, and rises nearly to the surface of the water, by which it will plainly be seen that the water on each side of the fire-flue is kept in a circular motion.



The boiler and pump rooms, as in the previous case, are of brick, and are connected with a neat dwelling for the use of the engineer in charge.

The system consists of about 22,000 lineal feet of piping, with the necessary hydrants and valves, and also an elevated storage tank, same as shown in cut in connection.

Near the pumping station, for the convenience of the fire department, is erected a reel house and hose tower. The tower is 60 feet high, and is provided with an apparatus for drawing the hose up to dry. The department is furnished with 1000 feet of hose with all the latest improved attachments, and two hose reels which are operated by hand.

The final test, which was conducted by Mr. Galt, was a repetition of the success met with at Amherstburg, and the system has been found to even more than fulfil the highest anticipations of its promoters; and the citizens now congratulate themselves on their fire protection and domestic water service.

# DIAGRAMS.

By John A. Duff, B.A., Grad. S.P.S., Fellow in Engineering.

From the time when man first invented picture-writing up to the present day, diagrams have been extensively employed as a means of communicating thought and of individual study.

Much of the time allotted for the reading of this paper might be occupied in giving instances of the use of diagrams in the arts and sciences, and in every-day life; but as it is intended to treat of the nature of diagrams rather than their application, no such enumeration will be attempted.

The examples which are given for the purpose of illustration are drawn almost entirely from Mechanics—though this is by no means the only science in which diagrams play an important part. In these examples the object is not to prove theorems in Mechanics, but merely to elucidate the nature of the diagrams employed in the proof. An exception has, however, been made in the case of the funiculiar polygon, the importance of the proposition proved by it seeming to warrant special mention.

A Diagram has been defined to be "a figure drawn in such a manner that the geometrical relations between the parts help us to understand relations existing between other objects."

The Diagram is of great value as an instrument of scientific investigation. Appealing directly to the eye, and presenting the argument in a concrete, realistic form, it makes it more definite and intelligible. By reference to letters or symbols placed at convenient points or lines of the diagram, the language in which the argument is stated is rendered more concise; and by the limitation placed upon our thoughts, they are more easily concentrated on the problem before us.

Diagrams are classified according to the manner in which they are intended to be used. Those which are not essential to the argument, and which are intended merely to afford a visual representation of the subject, are called Illustrative Diagrams or Diagrams of Illustration. The figures of Euclid furnish a familiar example. In this class of diagrams the argument proceeds by pure logic, and the diagram is satisfactory if the representation is clear.

The other class of diagrams consists of those which are drawn in such a manner that the magnitude of any quantity represented in the diagram may be obtained by direct measurement. Diagrams from which measurements are intended to be taken are called Metrical Diagrams. It is essential that they should be drawn as accurately as possible, clearness being of secondary importance. Illustrative Diagrams which are sufficiently accurate may be used for measurement, and Metrical Diagrams which are sufficiently clear may be used for illustration.

Those methods in which Metrical Diagrams are employed are called Graphical methods. There are two systems of Graphics: in one the diagram is used for the purpose of calculation, in the other merely for the representation of results.

The method of Graphical Representation depends upon the fact that magnitudes can be represented by lines as well as by numbers. If a certain length be taken to represent unity, twice that length will represent two, three times that length three, and so on. The *scale* to which the drawing is made, is indicated by giving the length which is taken to represent unity, or (which is the same thing) by giving the number of units represented by one inch on the paper.

The simultaneous values of two independently varying quantities may be represented graphically by employing the Cartesian system of co-ordinates, one quantity being represented by the ordinate, the other by the abscissa of a point. For example, in Statistics, if it is desired to represent the population of a country for a series of years, the years may be represented by the abscissæ, and the population for each year by the corresponding ordinate.

The velocity-space and velocity-time diagrams employed in Dynamics are examples of Graphical Representation. In velocity-time diagrams the abscissæ represent times, and the ordinates velocities. The scale of the one will be so many *seconds* to the inch, and of the other so many *feet per second* to the inch. Accordingly, if the velocity of a particle at different instants has been determined by calculation or observation, and the results plotted on a diagram in the manner indicated above, a series of points will be determined such that the ordinate of each point represents the velocity at the time given by the abscissa. The curve passing through these points is called the velocity curve, and, when drawn, the velocity at any instant may be found by measuring the length of the ordinate whose abscissa represents that instant. In the same manner, an acceleration-time diagram may be drawn in which the ordinates represent the acceleration of the particle at the different instants of time. If the scale to which time is drawn is the same in each, the two diagrams may be superposed so that different lengths on the same ordinate represent the velocity and the acceleration at the same instant.

In velocity-space diagrams, the velocity and the distance traversed are taken as the independent variables. The abscissæ represent distances, and the ordinates velocities, just as in the velocity-time diagrams. Acceleration-space diagrams may be drawn and may be combined with velocity-space diagrams in the manner indicated for acceleration-time diagrams.

It follows from a consideration of the above examples that if the ordinates representing a number of suitably chosen and known values of any varying quantity be constructed, and the curve passing through their extremities be drawn, any intermediate value may be determined directly by scale. In this manner interpolation may be performed without the use of numerical tables.

One advantage of Graphical Representation is that it affords a simultaneous view of the different values, by means of which a more intelligent comparison may be instituted between them. If several values calculated from a formula be plotted by the co-ordinate method, the curve joining them presents a picture of the law which the formula represents. If the isolated results of experiment are plotted, the curve joining them may enable us to deduce the formula which embraces such results.

Another advantage of Graphics is the flexibility of the unit of measurement. It is known that numerals do not convey any definite idea of the magnitude of a very large quantity, much less of the relative magnitude of two or more very large quantities. But if a small linear unit is chosen, very large quantities may be represented graphically by lines of moderate length, and a good idea of their relative magnitude may be obtained. Similarly, by choosing a large scale a better comparison may be instituted between very small quantities represented graphically than when represented numerically.

The method of Graphical Representation is frequently employed in the observation of phenomena. Such diagrams are usually described automatically, and in many instances furnish the only accurate means of measuring the quantities involved. In most cases, the mechanism is so arranged that a card or strip of paper moves with a known uniform velocity in a given direction, while at the same time a pencil which marks on the card moves in the perpendicular direction, in accordance with the variations in the phenomenon observed. Thus the pencil traces out a curve such that each ordinate represents the magnitude of the quantity observed at the time or place indicated by the corresponding abscissa. For example, the Indicator Diagram of the steam engine furnishes a means of measuring the working pressure of the steam for every position of the piston, from which data the efficiency of the steam engine may be calculated.

It has likewise been customary for many years to record various vibratory movements by means of Diagrams. Thus, the vibrations of sounding bodies have been recorded by passing a plate of smoked glass under a pointer attached to the vibrating body. This method is as truly a writing of sound vibrations as the method of the phonograph, and it is most probable that this use of Diagrams suggested to the inventor of that remarkable instrument the idea of writing sounds in wax.

Graphical Calculus is the method of using Diagrams for the purpose of calculation: For example, to find the square root of $n$, having chosen the scale, measure off on a straight line the distance which would represent $n + 1$. On this line, as diameter, construct a circle, divide the diameter into two segments of length, $n$ and $1$, and through the point of division draw the chord perpendicular to the diameter; then half the length of this chord is the square root of $n$.

Thus the object of the Graphical Calculus is to construct a Diagram in such a manner that certain unknown quantities may be determined by direct measurement. The object of Graphical Representation is simply the representation of results. Hence diagrams and methods which are useful in Graphical Representation may not be suitable for Graphical Calculation. In the example of the Graphical Representation of velocities which has been given above, the magnitude is represented by the ordinate to the curve, but the direction and sense are not indicated. Accordingly, though this method may be convenient for the representation, it is not adapted to the calculation of velocities, except in the case of constrained motion, such as occurs in machines where the direction and sense of the motion are determined by geometrical conditions.

In order to fully represent a velocity by a straight line, recourse must be had to the theory of vectors. Any quantity which may be specified by magnitude, direction, and sense is called a vector quantity, and lines representing such quantities are called vector lines. Displacements, forces, velocities, accelerations, are examples of vector quantities.

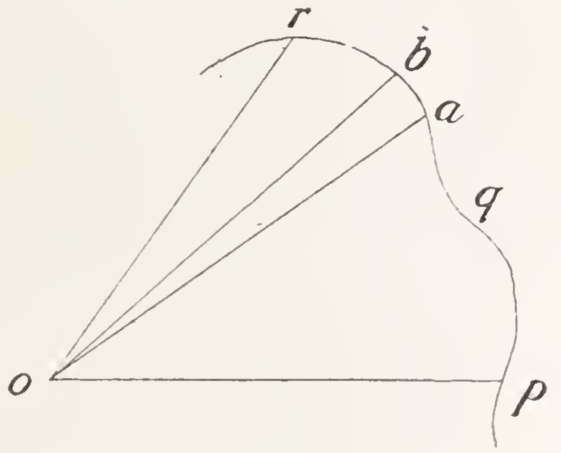
Vector Diagrams are those which consist of vector lines. The principal problem connected with vector diagrams is the determination of the resultant of a set of displacements, forces, or other vector quantities. A convenient starting point having been chosen, let the vector line of one of the quantities be drawn, and from its extremity the vector line of another, and so on until all the vector lines are drawn. The figure so formed will be, in general, an open polygon, and the resultant will be represented by the vector line joining the initial to the final point.

This proposition is self-evident in the case of displacements, and by analogy it may be inferred to be true also for other vector quantities. The best proof, however, that it applies to other vector quantities is in the fact that all propositions logically deduced from it are found to agree with the results of experiment and observation.

In considering the relation which acceleration bears to velocity, it may be convenient to represent the velocity at each successive instant. If the velocity vary in direction, and if the velocity vectors for each instant be drawn from any origin, a series of radial lines will be obtained, which are indefinitely close to one another, and the locus of whose extremities will form a curve which is called the Hodograph. If the velocity does not vary in direction, the radial lines will be coincident, and the Hodograph will be a straight line.

In *Fig. 1* let $o$ be the origin from which the velocity vectors are drawn; $pqr$, the locus of their extremities, will be the Hodograph. Let $oa$, $ob$, be the velocity vectors at the beginning and end of a very small interval of time $\delta t$. The velocity which must be compounded with $oa$ in order to produce the velocity $ob$ will be represented in magnitude, direction, and sense by the velocity vector $ab$. That is to say, $ab$ is the vector of the change in the velocity in the time $\delta t$. Hence $\frac{ab}{\delta t}$ is the average rate of change of the velocity during the time $\delta t$, and, since $\delta t$ is very small, $\frac{ab}{\delta t}$ may be taken for the acceleration during the time $\delta t$. But $\frac{ab}{\delta t}$ is also the velocity with which the Hodograph is described. Hence the velocity with which the Hodograph is described is equal to the acceleration of the motion.

*Fig. 1*



Since the direction and magnitude of the velocity are given by the tangent to the path and the speed with which the path is described, and since the direction and magnitude of the acceleration are given by the tangent to the Hodograph and the speed with which the Hodograph is described, the acceleration is the same function of the Hodograph as the velocity is of the path. Accordingly, the Hodograph is sometimes called the *curve of acceleration.*

Graphical methods have been more generally employed in Statics than in Kinematics or Dynamics, because in Statics the motion of bodies is not taken into consideration, and the diagrams are less complicated. In fact, the most satisfactory proof of the principal problem of Statics is by the Graphical method. As it furnishes an excellent example of Graphical analysis, it may not be out of place to reproduce it here.

The problem is "To determine the resultant of a set of forces acting in one plane on a Rigid Body."

A Rigid Body is an ideal substance which is perfectly stiff, or in which there can be no relative motion between the parts, however small those parts are supposed to be. Since there can be no change of shape in a Rigid Body, the effect of any force acting on a Rigid Body will be the same at whatever point in its line of action the force is supposed to be applied.

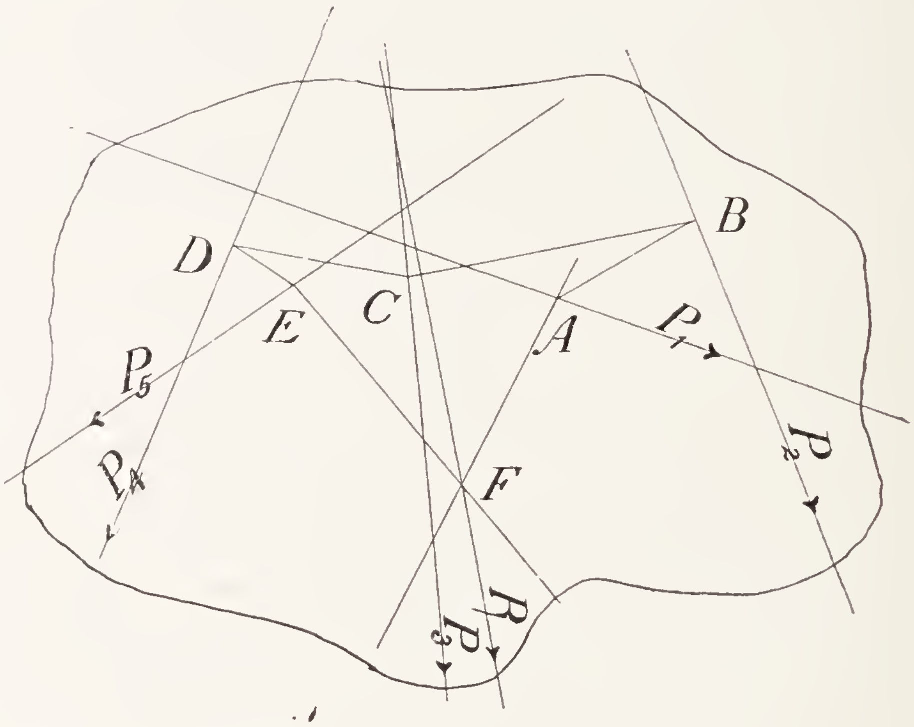
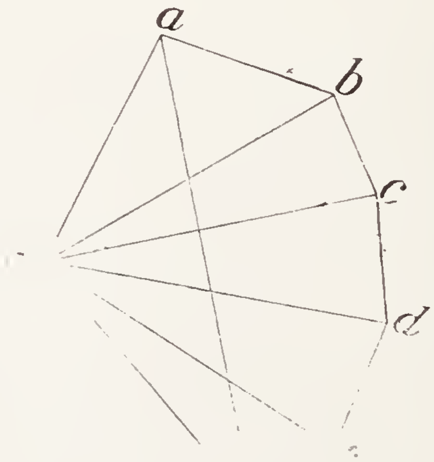


*Fig. 2*

Any force is fully described if the magnitude, direction, sense, and point of application are given. A force is a vector quantity in so far as it involves magnitude, direction, and sense.



Forces lying in one plane and acting on a Rigid Body may be divided into two classes, according as their directions do or do not all pass through one point. When the directions all pass through one point, all the forces may be considered to be applied at that point, and their resultant may evidently be applied at the same point. The magnitude, direction, and sense of the resultant may be determined by applying the theorem of the vector polygon. The resultant will then be fully determined.

When the directions of the forces do not all pass through one point, to determine the resultant:

In *Fig. 2* let $P_1$, $P_2$, $P_3$, $P_4$, $P_5$ be a set of forces acting in the same plane on a Rigid Body, but whose directions do not all pass through one point. From any point $a$* draw $ab$ the vector of $P_1$, $bc$ the vector of $P_2$, $cd$ of $P_3$, $de$ of $P_4$, $ef$ of $P_5$. Then $abcdef$ is the vector polygon of the forces $P_1$, $P_2$, $P_3$, $P_4$, $P_5$. In the plane of the vector polygon choose any point $O$ and join $oa$, $ob$, $oc$, $od$, $oe$, $of$.

In the line of action of $P_1$ take any point $A$. Through $A$ draw $FA$ parallel to $oa$, and $AB$ parallel to $ob$, intersecting $P_2$ in the point $B$: through $B$ draw $BC$ parallel to $oc$, intersecting $P_3$ in $C$: through $C$, $CD$ parallel to $od$, intersecting $P_4$ in $D$: through $D$, $DE$ parallel to $oe$, intersecting $P_5$ in $E$, and through $E$, $EF$ parallel to $of$. $FABCDEF$ is called a *funicular polygon*, of which the first and last lines are $FA$ and $EF$, and of which the point $o$ is the *pole*.

The resultant of the forces $P_1$, $P_2$, $P_3$, $P_4$, $P_5$ will be represented by the vector line $af$, and its direction will pass through the intersection of $FA$ and $EF$.

The body being rigid, the force $P_1$ may be considered to be applied at any point in its line of action. Let it be applied at $A$.

Referring to the vector polygon $aob$, it will be seen that the force $P_1$ applied at $A$, and whose vector is $ab$, may be resolved into two components acting at $A$ whose vectors are $ao$ and $ob$. But the force acting at $A$ whose vector is $ao$ must act along $FA$, because $FA$ was drawn parallel to $ao$, and the force whose vector is $ob$ must act along $AB$, because $AB$ was drawn parallel to $ob$. Accordingly, instead of the force $P_1$ there may be substituted a force along $FA$ whose vector is $ao$, and a force along $AB$ whose vector is $ob$. In the same manner, the force $P_2$ may be supposed to be applied at the point $B$; and by referring to the vector triangle $boc$, it may be seen that instead of $P_2$ there may be substituted a force along $AB$ whose vector is $bo$, and a force along $BC$ whose vector is $oc$. Similarly, instead of $P_3$ there may be substituted a force along $BC$ whose vector is $co$, and a force along $CD$ whose vector is $od$: instead of $P_4$ a force along $CD$ whose vector is $do$, and a force along $DE$ whose vector is $oe$: and instead of $P_5$ a force along $DE$ whose vector is $eo$, and a force along $EF$ whose vector is $of$.

But the force along $AB$ whose vector is $ob$ is balanced by the force along the same line whose vector is $bo$, the force along $BC$ whose vector is $oc$ is balanced by the force whose vector is $co$, and so on. Of the ten forces which have been substituted for the five original forces, there are left the two unbalanced forces, $ao$ acting along $FA$ and $of$ acting along $EF$. These two forces may be considered to be applied at $F$, the intersection of $FA$ and $EF$. Their resultant will also act at the same point, and its vector will be given by the line *af*. Hence the resultant of the set of forces, $P_1$, $P_2$, $P_3$, $P_4$, $P_5$, passes through *F*, the intersection of the first and last lines of the funicular polygon, and its vector is *af*, the line joining the first to the last point to the vector polygon.

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* In what follows the order in which the letters are given indicates the *sense* in which the line is taken.

If the line *af* passes through *o*, the pole for the funicular polygon, then *FA* and *EF* either coincide or are parallel, because each was drawn parallel to the line *oaf*. If *FA* coincides with *EF* the funicular polygon is said to close, and the set of forces reduces to two forces whose vectors are *ao* and *of*, and whose line of action is in *EA*. The resultant is evidently that force along the line *EA* whose vector is *af*. If *f* coincides with *a*, this resultant becomes zero and the set of forces will be in equilibrium. When *f* coincides with *a*, the vector polygon is said to close. Hence the conditions of equilibrium are:

(1) That the funicular polygon should close.

(2) That the vector polygon should close.

Again, if *FA* is parallel to *EF* but does not coincide with it, the set of forces will reduce to two parallel forces. If *f* does not coincide with *a* these two parallel forces will be unequal, and will have a single resultant, a point whose line of action may be obtained by choosing a new pole *o′* and drawing a new funicular for the vector triangle *aof*. But if *f* coincides with *a*, the set of forces will reduce to two equal and parallel but opposite forces, acting along *FA* and *EF*. Such a pair of forces form a couple and have no single resultant. Hence the conditions that a set of forces should reduce to a couple are:

(1) That the vector polygon should close.

(2) That the funicular polygon should not close.

The point *A* might have been taken anywhere on $P_1$, and accordingly an indefinite number of funicular polygons might have been constructed with the same pole *o*, but the corresponding sides in each would have been parallel. But if funiculars be drawn for two different positions of the pole *o*, the corresponding sides in each will not be parallel. The pole *o* may be chosen anywhere in the plane of the vector polygon, and the starting point *A* may be taken anywhere along the line of action of $P_1$; accordingly, there may be constructed an indefinite number of sets of funiculars, and there may be an indefinite number in each set, but all the polygons of each set will have their corresponding sides parallel.

It will be seen that the Graphical Calculus possesses the same characteristics which belong to the method of Graphical Representation.

The system of thought is purely synthetical—before any unknown quantity can be used, it must be determined. This may seem at first sight to be an inconvenience when compared with Analytical methods in which the unknown quantities which are used in the investigation, but not sought after, may often be eliminated. But Graphical methods being more direct require the use of fewer of these unknown quantities, and the calculation of them, Graphically or otherwise, is often a necessary step in the calculation of the desired quantity. The accuracy of the calculation is limited by the accuracy of the draughtsman and his tools. It is generally sufficient for practical purposes; and whilst the practical engineer is continually becoming more expert with his drawing instruments, he is at the same time becoming less familiar with Analytical methods and formulæ.

Graphical Calculus aims at giving general methods, at formulating a routine to be followed in the solution of each problem, but it cannot give general results—results by means of which particular problems may be solved by merely inserting particular values. But to the engineer this is no serious disadvantage, for he has usually to deal with particular problems, and he can employ the general methods of Graphics to obtain the particular results which he requires.

If the results of Graphical Calculus are less general in their application, the meaning is not half concealed in a mass of formulæ of which the practical engineer knows little or nothing; and to understand Graphical methods, it is not necessary to have that extensive knowledge of Mathematics which is so essential to Analytical investigations, and which requires years of study to obtain.

Many advocates of Graphical methods have spoken very disparagingly of Analytical, and those who follow Analytical methods have a tendency to ignore Graphics. The proper view is to consider the two systems as complementary, and not opposed to each other. There is no student of Graphics who is not benefited by an extensive knowledge of Analytical methods, and no student of the latter who should not also study Graphics. The one furnishes a most useful check upon the accuracy and elucidates the methods of the other, and no important engineering work should ever be undertaken, in the calculations for which both methods have not been employed.

# RETRACING OLD COMPASS LINES.

By J. L. Morris, C.E.

The compass used by land surveyors in making new surveys and retracing old ones has generally a needle five or six inches in length, about one-quarter of an inch in depth, and one-sixteenth of an inch in width. The needle tapers towards the ends, and becomes nearly a fine edge.

The graduation is made to half a degree, and with this fine needle, as low as ten minutes, and even five, can be read between the divisions. Older compasses had sights screwed to the compass box, which were very troublesome in a rough and thickly-wooded country, owing to their catching in the brush and striking projections, but the folding sight has done away with this objection. A staff cut in the woods and fitted to a steel point carried by the surveyor is satisfactory. Until a few years ago the majority of surveyors showed their courses as magnetic without giving the variations of the compass from true north ; and in cases where the original boundaries have been destroyed, it is only a question of approximately determining the original boundaries, even with a correct point to start from ; the nearness to a correct line depending upon the number of magnetic observations taken by the surveyor in that locality. Having no information as a basis for retracing my first compass line, enquiries were made from three surveyors, with the following result: (1) "I cannot tell you accurately what the change is, but somewhere about a degree in every twelve years." It was found that the change was a degree in every eighteen years. (2) "There is no reliable change of variation to suit compass lines owing to the careless work of surveyors forty or fifty years ago." It has been found that there is a change which suits the great majority of compass lines. (3) "Compasses differ in their magnetic north, and the change of variation at the same place may vary with different compasses from two and a half to four and a half minutes every year." So far the work by five or six different surveyors has been found to agree with the same change of variation. The changes in variation are placed under four heads: Irregular, Diurnal, Annual, and Secular.

You have observed, if retracing a line in a hilly or mountainous district, that at times the needle of your compass will differ two or perhaps fifteen degrees from your course of the last sight on the line. This may be attraction from iron in the vicinity, or, if not in a rocky, broken country, might be credited to magnetism in the air from some thunder or other magnetic storm. There has been one case where the needle has pointed at right angles to its true course. It is not always expected that the needle will become lively and sensitive under this attraction, but at times will assume a very dead manner, and hard to move out of its course. You may think that the pivot on which your needle swings may be at fault, but will finally conclude that there is a magnetic pole directly under the point of your staff. These may be the causes for Irregular changes.

Diurnal or daily changes will never be noticed during work in a level country, but probably after running over a hill, and a few hours afterwards looking back from another hill, you will find that the course now reading on your compass will not agree with the line back, and may require a change of about fifteen minutes to do so. The effect is that you arrive at your destination with a line of the same course at the ends and curved in the middle. A continuous line from day to day would take the form of a snake. This change in variation explains the reason why a transit line will cross and recross a compass line. In practice, this change of variation does not interfere with the work of a surveyor retracing an old line.

The Annual change is a variation in the Diurnal change, differing in summer and winter, but does not affect us in our work. If correct observations were taken from year to year, it would be observed that the magnetic bearing of the same line will change from year to year, and is known as the Secular Change of Variation. The following table, formulated from a few cases in practice, gives the date of the original survey, magnetic course of line, district, date of retracing, and the course of retraced line :

| *Date.* | *Course.* | *District.* | *Retraced.* | *Course.* | *Change.* | *Per Year.* |
|---|---|---|---|---|---|---|
| 1841 | *N*21°*E* | Ottawa River, Renfrew County. | 1891 | *N*23°45′*E* | 2°45′ | 3′.3 |
| 1845 | *N*21°*E* | Petewawa River. | 1891 | *N*23°30′*E* | 2°30′ | 3′.3 |
| 1846 | *N*21°*E* | Ottawa River, Renfrew County. | 1889 | *N*23°15′*E* | 2°15′ | 3′.1 |
| 1846 | *N*21°*E* | Petewawa River. | 1891 | *N*23°30′*E* | 2°30′ | 3′.3 |
| 1874 | *N*88½°*E* | Pembroke. | 1891 | | | |

It will be observed that the changes in variation show a nearly uniform change. Considering that the question of retracing old compass lines is now becoming of greater moment, owing to the increase in value of property and timber, it would be of great service to surveyors in certain districts to have the variation at different places and at regular periods ascertained. This information, compiled into a table of "Changes of Variation," would be of great service to coming surveyors. It would be found that the work done with a compass, rather than being under mistrust, would be satisfactory and more correct.

# A SHORT PRACTICAL ESSAY ON "THE SEA AND ITS WAVES."

By V. G. Marani.

The subject upon which I am about to enter is one which, although vastly interesting, is generally paid little or no attention to, a fact which, if we consider, is not at all surprising, as busy shoremen, when on land, find so much to interest and occupy time and attention that they scarce give a thought to what at first sight appears as a vast waste of gloom and solitude.

The ocean, occupying about four-fifths of the entire globe, is in itself a perfect world of life, though rarely of peace. Clever scientists tell us that the ocean water is composed of 28 elements, the principal being of course those which give it its liquid state; namely, *oxygen* and *hydrogen*, in which are contained *chlorine*, *nitrogen*, *carbon*, *bromine*, *iodine*, *fluorine*, *sulphur*, *phosphorus*, *silicon*, *sodium*, *potassium*, *boron (?) aluminium*, *magnesium*, *calcium*, *strontium*, and *barium*, including *silver*, *iron*, and *copper*. These various substances, however, exist only in infinitesimal proportions; of the metals, silver perhaps being the most abundant, as Reclus informs us that the ocean contains 2,000,000 tons of silver. Sodium chloride (common table salt) forms three-fourths of the salt state of the ocean.

If the waters of the ocean were to evaporate, we should have left an average of about 2″ inches to every fathom of water; or, taking three miles as the average depth, were the ocean then to evaporate, we should have left a layer of salt about 230 feet in mean thickness. The saltness or (specific gravity) of the ocean, however, varies in all parts according to the amount of fresh water contributed by rain or rivers, and the direction of currents and counter currents. The average specific gravity of oceans with deep basins is 2.8 per cent. more than the same bulk of distilled water. In the Mediterranean, however, the specific gravity is 2.9 per cent., more owing probably to the evaporation, caused by the warm climate to which this sea is subjected, slightly exceeding the amount received from rivers and rains. The exact reverse takes place in the Black Sea, where the specific gravity is only 1.6 per cent., owing to the large amount of fresh water received from its numerous rivers. It has also been an established fact that the waters of the Southern Hemisphere are considerably less salty, and therefore lighter, than those of the Northern Hemisphere. We can now proceed to discuss a subject that will involve what has, as yet, only been approximately ascertained, namely, the greatest depth of the ocean. One of the deepest soundings taken with success was between the Pacific and Indian oceans, south of the East Indian Islands, by Captain Riggold, who found bottom at 8¾ miles.

Young, during his sounding cruise, gave the North Atlantic a mean depth of 3,280 feet, and in the South Seas his estimated mean depths ranged from 19,500 feet to 22,000 feet. But Sir John Herschell, for his practical use, took the probable maximum depth of the ocean as a little under 5 miles. However, results obtained at such depths must be very vague, it being practically unsafe to rely on the accuracy of soundings (by mechanical means) at a greater depth than 2 or 3 miles. Many efforts have been made to sound some parts of the Pacific Ocean, but, as yet, all have failed to gain bottom. The currents of the ocean, in turn, also form a leading feature in the study of the sea and its waves. Currents can be divided into two great classes, namely, drift and stream currents; the former moving in a direction more or less parallel to the wind in each district, and which, when deflected by meeting with an obstacle (such as an island or line of coast), flow on in a new direction until their impetus is expended under the name of stream currents The currents of the ocean are very numerous, some of the most important being the Gulf Stream, Equatorial, Humboldt's, and American Arctic currents, including several others, each and all of which faithfully, and to fixed laws, perform their principal functions in climatizing countries and islands.

In low latitudes, all round the world, we meet with westerly currents, and in every case there is an easterly counter current flowing close along the Equator between the drift currents of the two Trade Winds. In the middle latitudes, however, the currents are reversed, and are generally easterly. In fact, in each of the five great oceans vast bodies of water are continually circling round in eddies, the Equatorial current taking the water westward, and the return currents, like the Gulf Stream, bringing it eastward again. This may be expressed simply by the following theorem from "Dr. Haughton's Physical Geography": "Given a permanent system of constant continuous circulation in any ocean, if any vertical plane be supposed drawn across the ocean, equal quantities of water must cross that plane from right to left, and from left to right, in a given time; for, if possible, let it not be so, then there will arise a difference of sea level at the two sides of the supposed plane, and the hypothesis of constant continuous circulation will become impossible."

Having roughly discussed the density, depth, and currents of the ocean, we now come to the phenomena of sea waves, the formation, height, and velocity of which are either more or less influenced by the above subjects.

Landsmen are wholly indebted to the sailor for at least the courtesy of giving "faith and full credence" to what they tell us about what they have actually seen and suffered, and to me nothing seems so obnoxious and disheartening as the reception which these "stay-at-home travellers" generally exhibit in their criticism of what seamen tell them as to the height of sea waves, etc. But once again to our subject. The sea is very seldom, if ever, at rest, and even during a calm under the burning rays of a tropical sun the glassy surface is seldom motionless; for long swells, causing the ship to roll, are sufficiently perceptible to tantalize the sailor with the thought that the breeze which mocks his desires is blowing freshly elsewhere. We can quite easily understand that, were it not for the wind, the sea would (under natural circumstances) present a smooth glassy surface, and therefore the wind now aiding, now retarding the currents, or ebbing and flowing, raises the sea into waves, more or less high, which roll regularly onward, or are dashed against or across one another. Owing to the sudden changes of wind or other numerous causes, waves sometimes become so confused and irregular that it is absolutely impossible to ascertain their direction, height, or speed. Sometimes, by piling upon each other, they more than double their natural height, and at other times they equalize the surface by throwing billows into furrows. Now, as already stated, the specific gravity of the water is one of the great features in the height of waves, and according as to whether the water is more or less dense, so is it also more or less susceptible to motion. Hence, to an equal wind, the waves of Lake Superior would exceed those of a lake of sea water equal in area and depth.

The waves of the Mediterranean are far exceeded by those of the Atlantic, while these latter are also exceeded by those of the Antarctic Ocean, which spreads over an entire hemisphere. Admiral Smyth estimated the Mediterranean wave at about 20 feet from crest to hollow. Scoresby, in 1848, gave the Atlantic wave an average of 30 feet from crest to hollow; but Dumont d'Urville, an old sailor of yore, asserts having seen waves from 80 to 100 feet high, to the depths of which the ship descended as in a valley, and M. Fleuriost de Langle, attests the truth of his statement. By the appearance of a troubled sea, one might suppose that the waves travelled, but such is not the case; waves themselves do not travel, their movement horizontally being irregular, and the water practically remaining in the same place. But it is the motion only which goes on; and it is the foaming crest, which, curling over the summit of the wave, dashes down the slope in front, not infrequently carving for itself a path of wreck and destruction. The apparent displacement of billows can only approximately be ascertained; and as the depth of the ocean increases, the more approximate will be the results. The velocity with which this displacement takes place undoubtedly depends mainly on the power and duration of the wind, but this velocity is greatly diminished by, and bears an ascertainable relation to, their magnitude and the depth of water over which they travel. It is said that the width of a wave (which is measured from trough to trough) is, on an average, about 15 times its height. Hence, if the average maximum wave be taken at 40 feet, it will, at its base, also extend over 600 feet or so of water.

Prof. Airey informs us that the displacement of a wave 100 feet in width and in water about 164 fathoms deep will be at the rate of about 15 miles per hour, and that a wave 674 feet in width, and over the surface of a sea 1640 fathoms deep, will move forward with a velocity of about 48 miles per hour. Thus, from investigation, we see that the Atlantic rollers of a mean width of, say, 200 feet, travel at the rate of about 40 feet per second (or 27 miles per hour).

Weber informs us that the motion of a wave can be felt in a vertical direction to 350 times its height. Therefore a wave 33 feet high will be felt at a vertical depth of about 2 miles. But at this enormous depth the motion must almost become an imaginary one, for below the surface this influence decreases in geometrical proportion. Taking a wave of about 40 feet high, it is said that the utmost disturbance of a water particle at a depth of 300 feet is not ½ inch from its mean position. Hence this shows that a mere surface effect is due to winds, and that the depths of the ocean are practically undisturbed by such causes. The actual force of wave motion can only be perceptible at about a depth of 30 or 40 fathoms. Since, therefore, we can by calculation infer the velocity of waves from their magnitude and the known depth of the ocean bed, it is easy to determine, by an inverse operation, what is the depth of the ocean itself, provided we know the rate of motion of the waves. And it is by this process that an approximate depth has been given to those parts of the Antarctic Ocean as yet never sounded by mechanical means.

Bache stated as one of the effects of an earthquake at Samoda, on the Island of Niphon in Japan, on December 23rd, 1854, that the harbor was first emptied of water, and then came in an enormous wave, which receded, leaving the harbor dry; this occurred several times. The self-acting tide-register at San Francisco, which records the rise of tide upon cylinders turned by clocks, showed that at that place, 4,800 miles from the scene of the earthquake, the first wave arrived 12 hours 16 minutes after it had receded from the harbor of Samoda. Thence it had travelled across the Pacific Ocean at the rate of 6½ miles per minute; the average depth over which this wave had travelled being about 14,000 feet. The *New York Sun*, in an article on "Sea Waves," informs us that carefully repeated experiments made by an experienced English navigator at Santander, on the north coast of Spain, showed the crest of sea waves in a prolonged and heavy gale of wind to be 42 feet high, and, allowing the same for the depth between the waves, the result would be a total height of 84 feet from crest to hollow; the distance from crest to crest was found to be 386 feet. The s.s. Gallia, on a voyage to New York during a gale in January last year, was boarded by a sea that her captain estimated at 100 feet high, also stating that had she been boarded by another such sea she would surely have foundered. We have other instances of the size and power of waves recorded to us from the logs of some of our transatlantic steamers, which, compiled and built as securely as iron can possibly be, yet, alas! only too often come to sad distress.

Quite recently we had the case of the s.s. Vancouver, whose chart house, and, unfortunately, the captain, who had just entered it, were both washed overboard by the single force of one sea. The Sardinian also lately lost her funnel by a sea, which also flooded the fireroom, smashed several of her boats, and killed three men. The Rijnald from Antwerp to New York, by one sea, lost her wheel house, five boats, and port rail; another sea, apparently of greater violence, tearing away the remaining rail, crushing the iron trestle back, and disabling the steering gear. It is true that few vessels could ever hope to withstand the tremendous power of those swift monster seas but for their enormous strength and the fact that they rarely receive the full impact of the wave.

Thomas Stephenson estimated that the force of the sea against Bell Rock Lighthouse is about 17 tons per square yard. In the Island of Skenyvon the heaviest calculated pressure is about 3½ tons per square yard. With such forces, the displacement of blocks from all the exposed works (sea walls, breakwaters, etc.) at Kingstown, Holyhead, Portland, and other places, which to us seems impossible, is only child's play to the tempest waves. At Leghorn, on the coast of Italy, the Atlantic waves have been known to seize blocks of stone weighing several tons and hurl them like playthings on the dykes.

At Cherbourg, on the north coast of France (noted, after the labor of over half a century, for its immense artificial breakwater and fortifications for mounting 3,000 guns), the waves have been known to displace the heaviest cannon on the rampart. At Plymouth, a vessel weighing 200 tons was thrown to the very top of the dyke, where she remained erect and safe from the fury of the waves. At Bara Head, in the Hebrides, Thomas Stephenson states that a block of stone 43 tons in weight was driven more than 1¾ yards by the breakers.

At Peterhead, N.B., over 30 years ago, there was a great crowd of people down near the beach one day watching the swells come in from the most severe storm on record at the time. About two hours before high water three tremendous waves rolled in, and, breaking on the beach, carried away 315 feet of a great bulkhead built 9½ feet above high water of the spring tides. One piece of the wall weighing 13 tons was carried 50 feet. Two hours exactly after high tide, three more waves came in of a similar character, but doing less damage. This was the first case on record in which the formation of big seas was connected with the time of the tides, but similar observations have been frequent since then.

It is on record that the waves of the German Ocean once broke in two a solid column of freestone 36 feet high and 17 feet in diameter at the base. The diameter at the place of fracture was 11 feet. At the top of Bound Skerry of Whalsey, in Zetland, the waves have broken out of their beds, which are 85 feet above the level of the sea, blocks of stone weighing from 8 to 10 tons.

At Tillamock Rock Lighthouse, situated in the Pacific off the coast of Oregon, a stone weighing 82 pounds was thrown by the force of the waves to the top of the lightkeeper's house, 110 feet above the sea level. During the same gale, the waves were so high that the water came down the chimney of the boiler-house of the fog siren in torrents and poured out through the tubes of the boiler. The chimney is 130 feet above sea level. The spray also entered the cowl of the chimney over the lamp, which is about 150 feet above sea level, and ran in streams to the bottom.

An instrument called the *marine dynamometer* has been made with a view to accurately measure the force exerted by waves. It has a known surface for the water to impinge on, the force of the impact being transferred to springs of known strengths. The distance to which the springs are compressed is self-registering. This instrument has recorded the force of the waves, not under extraordinary circumstances, as high as three tons to the square yard; and no doubt in exceptional cases this figure has been far exceeded. Smeaton, in his "History of the Eddystone Lighthouse," only too truly says, in referring to the power of waves, that "controlling these powers of nature is subject to no calculation."

It was during my last year's apprenticeship in the sailing ship firm of W. M. & Co., Liverpool, that the events I am about to narrate occurred. We left Hull, England, bound *via* Cape Horn for San Francisco, on the 2nd March, 1887, in the clipper ship, *Cedric the Saxon*, 1619 tons register, and truly one of the finest specimens in the merchant navy, being built by the late firm, John Reid & Co., of Glasgow, at a cost of $160,000.

How, like a living thing, she seems eager to get out of the musty docks; she frets her shapely sides; and how, after being towed well clear of

Spurn Head, she, scenting a fair nor'wester, gracefully spreads her sails, and, parting the seas with her clipper bows, bids farewell to England's shores!

Nought but the usual every voyage occurrences to record. In Channel at night great anxiety attends the sight of other vessels' lights, I having on one occasion counted no less than 198. The dangers of Channel over, we soon pass the Western Islands, and, as we near the tropics, we unbend our heavy canvas and replace it by a lighter and older suit. In the tropics the monotony of painting, overhauling of blocks, etc., which is only broken by the capture of a shark, turtle, or porpoise, the two latter making a splendid addition to our humble bill of fare; the former, when none other is to be had, also being acceptable, providing it be fairly young. With such and more numerous adventures than these we, after having struggled through the doldrums and southern tropics, find ourselves nearing the River Platte latitudes, where, as is generally the case, we had more wind than enough for our old sails, some of which we lost, to the silent but evident satisfaction of some of our tars, who, not forgetting the trouble they had bending them, would shake their heads and mutter, "I knew they would go; they were no use; ought never to have been bent," etc. A few nautical orders, followed by forcible words, has on such men a magical effect, and before long the ship is either in snug trim or hove to.

Soon a change of weather, and away we sailed, reaching the latitude of Cape Horn on our fifty-third day out. So far fortune had favored us; but as we neared this dreaded spot, we encountered strong westerly gales. For about three weeks we tacked, probably making by direct route about a true westerly course. The wind now greatly increased, and with it a sea of such force and violence that our galley and the after-part of the deck house were completely gutted, and we, now no longer able to tack, had to wear.

After about a week of hardships, such as only those who endured them can describe, we, to our dismay, began to realize that we were slowly but surely losing way; and that unless we were well to the southward of Cape Horn, we would inevitably drift on the rocky coast of some of the numerous islands. But on a Thursday night a change occurred, and none too soon, for, as the wind fell, we could distinctly hear in the distance the roaring and crushing of those enormous seas that, aided by a strong easterly current, were dashing most unmercifully on nature's rock-clad coasts. With what anxiety we awaited the coming morn as each monster sea raised us high, perhaps only to dash us with double violence on some hidden rock. Our barometer, reading about 27.60, continued to fall rapidly, as on, and with increasing velocity, came the south-easter. Taking no notice of a falling glass, we set all possible sail in order to further our distance from so dangerous a coast. Thus with fore and main lower topsails reefed mainsail, main upper topsail, and foresail, our ship dived and plunged her way through the seas, now and again to meet some great monster, that with its force would cause her (as if stunned) to remain still, and then (like some animal fighting against an equal foe) tremblingly continue her way. But rapidly the wind increased, and with it our speed, which, becoming dangerous against so great a head sea, compelled us to shorten in the mainsail; taking about two hours to haul the sail up, and five more before we had it furled. We were all utterly exhausted, so much so that two of the men, from aloft, no longer able to endure the exposure, had to lie down and an apprentice fell to the deck, a height of about 50 feet. He was fortunately picked up before being washed overboard by a sea, but only to endure weeks of internal pain.

But how could so fierce a wind battle against such a sea and current without some striking change? The waters, by this contrary hurricane, were simply piled into enormous wall-sided seas. After rising to prodigious heights, these seas would curl over, rushing after the ship in a terrifying manner. We could not heave to. It was just as much as we could do (with the amount of canvas set) to keep sufficient speed on the vessel in order to outreach these curling crests. Saturday morning found all hands on the poop—none cared to go below—all too anxious for the safety of the ship and their own lives.

At 8 a.m. an Englishman and I took the wheel, with orders to keep the wind fair behind us. How fearful the motions felt to me as clinging to the wheel, I would feel my weight lifted almost off the deck as the ship plunged into the trough, and, unable to check her mad rush in a moment, would half bury her nose in the seething foam; while after her rushes, the crest of the monster sea she has just descended. But soon the ship shakes herself free, and with mighty but well-spent efforts rises to the summit of the next wave, where, being again exposed to the full fury of the blast, with creaking spars and well-strained sails, she continues her downward plunges. Such was our state until about 11 a.m., when my mate at the wheel requested a "relieve," as he wanted something to eat; the captain eyed him with disgust, passed a remark to the effect that "he ought to think of his grave, not his belly," and then gave the order for another man at the wheel. The "relieve" had just been at the wheel ten minutes or so when, chancing to look at him, I saw his face turn pale, and, giving a yell of warning, he fled. I had no time to consider; I instinctively clung to the wheel; I saw what was coming, and, for the moment, I felt how insignificantly small and helpless the ship was. As this monster sea approached us, I heard the mighty hissing and crushing of its dangerous crest; then, with a motion that was both confusing and sickening, the ship shot upward, but alas! just too late. For one moment I felt the pressure on my back of the sea, which next moment carried both the wheel and me with it, and, raising me off the deck, finally left me clinging to the main rigging. The sea had passed, leaving behind a path of wreck and destruction. The ship, with her sails aback, now gathered stern way, and slowly began to bury herself in the foaming, boiling sea. It is now hard to say what we did: excited, nay, almost mad, each one did what he thought best for the safety of the ship. Tanks of oil were torn out of the paint locker, and, after having been gashed with an axe, were thrown into the sea. Braces and sheets equally shared the same fate, and the ship, relieved of her sails, before long rode more freely, head to wind. She was indeed a wreck; her wheel, skylights, boats, and skids had all been washed away, while the bulwarks and rails were bent and distorted into such shapes as even to put to defiance the skill of a blacksmith. Not only our old mate (a sailor of 40 odd years standing), but also some of our most experienced sailors, maintained that they had never seen before such a spell of weather, or seas so dangerous and of such magnitude, their estimation of the one which boarded us being between 60 and 70 feet from crest to hollow. The barometer during this hurricane fell to the low reading of 27.42. Truly nature's elements were at war.

Xerif al Edrisi, one of the most eminent geographers of the Arabs, in the middle of the twelfth century, at the Court of Roger I., King of Sicily, composed a work which he styled, "The going abroad of a curious man to explore all the wonders of the world." The Atlantic is thus noticed: "No one has been able to verify anything concerning it, on account of its difficult and perilous navigation, its great obscurity, its profound depths, and frequent tempests, through fear of its mighty fishes and haughty winds; yet there are many islands in it, some peopled, others uninhabited. There is no mariner who dares to enter into its deep waters; or if any have done so, they have merely kept along its coasts, fearful of departing from them. The waves of this ocean, although they roll as mountains, yet maintain themselves without breaking; for if they broke, it would be impossible for a ship to plough them."

As we read these words, containing the ideas of bygone ages, it is with a feeling of pride and gratitude we acknowledge that to such men as Maury, Herschell, Scoresby, and others, we owe our present knowledge of the ocean with its once obscure secrets.

# HYDRAULIC CEMENTS.

By Edward F. Ball.

*Mr. President and Gentlemen,*—This paper will be devoted to the discussion of the effect of impurities usually found in cement, with descriptions of tests for their detection. The literature on this subject is meagre and conflicting. Gillmore treats of the process of manufacture at some length; but as he was the pioneer in cement testing, this work is not up to date. Considerable information can be obtained from the pamphlets published by manufacturers and dealers; but as the writers are usually prejudiced in their opinions, these must be taken "with a grain of salt." Baker's "Treatise on Masonry Construction" contains much valuable information on the subject.

Space does not permit of a detailed description of the American and German methods of cement testing, but such information can be obtained from the work last mentioned. Directions for the American method are enclosed in the samples which accompany this paper.

Before entering upon the subject of impurities, it will be necessary to briefly refer to the process of manufacture and the chemical changes which occur.

## PORTLAND CEMENT.

Artificial Portland Cement is made by *thoroughly* mixing together in suitable proportions *finely divided* clay and carbonate of lime (chalk, marl, or compact limestone), burning the mixture in kilns at a high temperature, and then grinding the burnt product to fine powder between ordinary millstones.

It is especially important that the ingredients be thoroughly mixed, finely ground, and correctly proportioned. No substance coarser than the one-thirtieth part of an inch will make cement, and the finer the ingredients are ground the better. Thorough mixing is even more important than correct proportioning, as the temperature in the kiln is not allowed to rise high enough to liquefy the mass, and, in order that the chemical changes may take place, the particles of clay and lime must be in close contact with each other; otherwise uncombined clay or lime will be left.

The first chemical change which occurs in burning is the expulsion of chemically combined water and carbon dioxide; thus calcium carbonate

$CaCO_3$, is converted into lime, $CaO$. The silica, $SiO_2$, which is present as silicate of alumina in the clay, is partly transferred to the lime, forming a double silicate of lime and alumina. A high temperature is necessary for the formation of this double silicate, but at a lower temperature the alumina, which was present in the clay as a base, plays the part of an acid, and, combining with the lime, forms aluminate of lime.

If the temperature is too high, a lime glass is formed which has no hydraulic properties; and if the burning be continued at this temperature, a solid crystallization between the silicates and aluminates of lime is formed, which also impairs the hydraulicity.

### THEORY OF THE SETTING OF CEMENT.

This may be briefly described as the crystallization of the double silicate of lime and alumina.

### IMPURITIES.

If by reason of imperfect proportioning, grinding, or mixing any portion of the lime fails to combine chemically with the silica or alumina of the clay, this is known as *free lime*, and, when the cement is fresh, it is in the form of $CaO$. Upon exposure to the air it absorbs moisture and becomes slaked; thus:

$$CaO + H_2O = Ca\,(OH)_2.$$

Upon still further exposure it slowly absorbs carbon dioxide and returns to its original composition, carbonate of lime:

$$Ca\,(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

When present in the unslaked form, $CaO$, free lime is one of the most dangerous impurities in cement, as upon the addition of water it slakes and expands, thereby disturbing the setting of the cement. This slaking is not rapid like the slaking of rich or fat lime, and often is not apparent for the first day. It frequently happens that samples of cement will stand a good tensile strain at the end of 24 hours, while at the end of 7 days the test will be very low; sometimes below the 24-hour test. This generally indicates free lime, and in such a case the samples should be exposed to the air for a week and a second test made. If this test comes up to the standard the trouble is due to the presence of free lime, and the cement should be accepted, provided the other tests are satisfactory, on condition that it be spread out and exposed to the air for a week or more before use. If the lime have sufficient activity, thin cakes of the cement immersed in water for a week will show cracks; but if the lime is not present in sufficient quantity, or has not the necessary activity, no cracks will appear.

Mr. W. W. Maclay, an eminent authority on cement, recommends exposing the pats as soon as they are hard to a high temperature, saturated with moisture for about three hours, and then boiling them for 24 hours. Free lime should not be present in excess of 2 per cent., especially if the cement be for use under water. It retards the setting of the cement and impairs its hydraulicity. When present in considerable quantity, the cement will disintegrate on immersion unless first allowed to become quite hard in air.

In determining the amount of free lime in cement by chemical analysis, it is customary to find the amount of $CO_2$ on the supposition that the lime is in the form of carbonate, and then calculate the amount of lime, 1 per cent. of $CO_2$ indicating 1.3 per cent. of CaO. This, however, is a very unreliable method, as before the lime can be converted to $CaCO_3$ it must first be hydrated and then carbonated. This requires a long time, if exposure to the air is relied upon to effect the change, as is usually the case. Hydrogen sulphide, $H_2S$, is frequently evolved with the carbon dioxide, and this also affects the accuracy of the test In the absence of any better method, the writer has determined the amount of free lime by expelling the $CO_2$ with dilute acid. The acid and cement were carefully weighed, before and after mixing, the difference indicating the amount of $CO_2$. The average of a number of tests should be taken, as the process requires great care to obtain accurate results.

Magnesia is another dangerous impurity in Portland cement. It may not prevent the cement from setting and becoming apparently as hard as though it were absent. For a long time it may remain inert, and perhaps for months there may be no apparent alteration. The magnesia, however, has an affinity for water: every two pounds of magnesia in becoming hydrated takes up and soldifies one pound or 27.7 cubic inches of water, and in bulk every ton of magnesia would have to find room for about 16 cubic feet of water. In finding room for this water the mortar becomes disintegrated. The action goes on whether in air or in water, but, as may be expected, more rapidly in water, and is especially disastrous in concrete work. Mr. Harrison Hayter, Vice-President of the Institution of Civil Engineers, cites instances where concrete works have failed, although built in the usual manner with cement that had stood the ordinary mechanical tests. The concrete set as hard as usual, but after a time expansion set in. In one case a vertical wall about 35 feet high was lifted about 2½ inches; in another a mass of concrete 16 feet thick had lifted from ½ to 1¼ inches. In every case a white substance of the consistency of cream was seen in the concrete. Mr. Hayter had this substance analyzed, and it was found to contain 80 per cent. of magnesian hydrate, consisting of about ⅔ magnesian oxide and about ⅓ water.

The writer made some experiments with 5 per cent. by weight of calcined magnesia added to Improved Union cement, a mixture of Union Hydraulic and Giant Portland. The magnesia was found to render the paste very plastic and easily worked. It retarded the time of setting and greatly decreased the strength of the cement. At the end of one week the pats were very soft; the outside was light gray and the interior the usual color. Briquettes made of the mixture had the following strengths:

| Time Setting. | Tensile strength in lbs. per square inch. | | | | | | Mixture. |
|---|---|---|---|---|---|---|---|
| | 1 day. | 2 days. | 3 days. | 5 days. | 1 week | 2 wks. | |
| 20 minutes. | 45 | — | — | — | 74 | — | Neat Cement. |
| 2 hours. | 1 | 2 | 3 | 5 | 19 | 36 | 5% Calcined Magnesia added. |

Good Portland cement should in no case contain more than 1 per cent. of magnesia.

*Sulphuric Acid.* By the rules of the École Nationale of Paris, if the sulphuric acid exceeds 1½ per cent., the cement is rejected on the chemical analysis alone. When Portland cement is properly burned it forms a very hard clinker, which is expensive to grind to the fineness now demanded by engineers, as the machinery requires constant repair. To render the grinding easier, iron slag meal is sometimes added to the cement clinker. This slag cement may be recognized by its lighter specific gravity (2.60), and by its color, which is a mauve tint in powder, while the inside of the water pat, when broken, is deep indigo. Its presence when mixed with Portland may be detected as follows: To a gill of water add about 80 drops of sulphuric acid. Into this drop 25 grains of the cement and stir rapidly with a glass rod, so as to prevent any setting, and while still stirring pour in, drop by drop, a solution of permanganate of potash (64 grains permanganate to 1 pint of water), until the red color remains permanent. Genuine Portland will require only 10 to 15 drops of the solution, whilst an adulterated cement will take considerably more (30 to 60), and a cement made from slag over 200 drops. The principle of this test is as follows: Solid permanganate of potash is at once decomposed by the addition of strong acids, but in water solution this decomposition does not at once take place except by contact with oxidizable substances. This action is apparent by the change of color, the deep purple being rendered colorless.

All Portland cements contain a small quantity of iron: thus with unadulterated cements a certain amount of the permanganate will be bleached, but cements containing iron in undue proportions will bleach a much greater quantity of the solution. A simple test for the same purpose is as follows: Place upon a clean silver coin a thin layer of cement, and drop on it a small quantity of dilute sulphuric acid (one acid to seven water), and afterwards rinse with water. If the cement be genuine Portland, the treatment will only slightly affect the color of the silver; but if slag be present in any notable proportion, a dark-brown stain will be produced.

Cement adulterated with slag and slag cement will be found finer ground and quicker setting than Portland, and it will attain its maximum strength in less time than the best Portland, but retrogression then takes place, which is most treacherous in its nature. The failure of the concrete construction of the Aberdeen Harbor Works is now attributed to the use of cement which was not true Portland, although at first it was considered that the action of the sea water was the cause; but examination of similar constructions built with good Portland cement many years previously proved that when the proper material is employed, and due care exercised in construction, permanency is assured.

*Salt* is often added to the water in cold weather to prevent mortar from freezing before it has set. Authorities differ regarding the effect of salt. The latest information on the subject is contained in the report of tests made at Governor's Island, New York Harbor, by Mr. John Gartland, for Col. D. C. Houston, U. S. Engineers. For salt-water tests sea water was used, and was found to increase the strength of the cement from 1 to 53 per cent., except in the case of Hoffman Rosendale, two months old. At three and six months this same cement gave higher results with sea water. About 330 briquettes from 9 brands of cement were tested, so the results seem entirely reliable. The general opinion of engineers, that sea water decreases the strength of cement, is probably based on Gillmore's experiments, which were not nearly so comprehensive as the above.

*Sugar* added to mortar has the same effect in preventing freezing that salt has. It increases the strength of lime mortar, especially in the centre of thick walls, but is a detriment to cement mortar. An excess of clay in cement is said by some to make the mortar more easily affected by frost, while a small excess of lime (not more than 2 per cent.) does not injure the mortar, and is much preferable to an excess of clay if exposed to the action of frost. Overclayed cements, if underburned, give a high test and set quickly, but they are liable to injury during burning by changes of temperature, while cement containing a slight excess of lime is not injured thereby.

Good Portland should be burned at a high temperature, which is indicated by high specific gravity (95 lbs. per cubic foot) and slowness in setting (2 hours or longer). The color indicates but little, since it is chiefly due to the oxides of iron and manganese. Gray or greenish-gray is considered best; bluish-gray indicates a probable excess of lime; brown an excess of clay. A mauve tint indicates adulteration with iron slag, and an undue proportion of underburned material is generally indicated by a yellowish shade, with a marked difference between the color of the hard-burned unground particles retained by a fine sieve and the finer cement which passes through the sieve. The fineness should be such that 90 per cent. by weight will pass through a sieve of 2,500 meshes per square inch made of No. 40 wire, Stubbs' wire gauge.

Made into cakes about 2½ inches square and ⅜ inch thick, and immersed in water immediately after setting, it should show no cracks at the end of a week.

The tensile strength should be about as follows, a very high breaking strength within the first four weeks generally indicating an unsound cement:

| 24 hours. | 1 week. | 1 month. | 1 year. | |
|---|---|---|---|---|
| 100<br>to<br>140 | 250<br>to<br>550 | 350<br>to<br>700 | 450<br>to<br>800 | Neat cement. |
| —<br><br>— | 80<br>to<br>125 | 100<br>to<br>200 | 200<br>to<br>350 | 3 parts sand to 1 part cement. |

The impurities should not be present in excess of the following quantities:

| | | |
|---|---|---|
| Magnesia | 1 | per cent. |
| Free lime | 2 | " " |
| Sulphuric acid | 1½ | " " |
| Ferric oxide | 4 | " " |

### NATURAL CEMENTS.

By natural cements are meant those which are obtained from natural stone containing lime and clay. The stone is quarried, broken into pieces, and burned in a kiln. The burnt cement is then crushed into fragments and ground between ordinary mill stones. The description of impurities in Portland cement is applicable to natural cement, except the part relating to magnesia. *Free* magnesia is as objectionable in natural cement as in Portland, but the greater portion of natural cement rocks are argillo-magnesian limestones. In burning, a triple silicate of lime, alumina, and magnesia is formed, which makes a good cement, but any free magnesia will absorb water and expand as in Portland. Natural cement is generally light-colored and quick-setting, and is especially adapted to sewer work and places where the mortar is exposed to running water before setting. The requirements for good natural cement are the same as for Portland, except as regards color, weight, tensile strength, and the presence of magnesia. The tensile strength of American natural cements should be about as follows:

| 24 hours. | 1 week. | 1 month. | 1 year. | |
|---|---|---|---|---|
| 40 to 80 | 60 to 100 | 100 to 150 | 300 to 400 | Neat cement. |
| — | 30 to 50 | 50 to 80 | 200 to 300 | 1 part sand to 1 part cement. |

### IMPROVED CEMENTS.

This name is given to natural cements mixed with Portland. The natural cements are usually light-colored and the Portland dark, so that the color of the mixture is of value in determining its quality. It is advisable to collect samples of the natural or "unimproved" cement, and also of the Portland used in the mixture. By comparing samples of the improved cement with these, a fair idea of its quality may often be obtained.

Two well-known brands are "Improved Union," manufactured by the American Cement Co., Egypt, Pa., and "Saylor's Improved Anchor." These cements have the following tensile strengths, as determined from tests of 900 briquettes from about 90 consignments made at the Division Engineer's Office, Lehigh Valley Railway (Buffalo and Geneva Branch), Batavia, N.Y.:

| 24 hours. | 1 week. | |
|---|---|---|
| 50 to 100 | 100 to 190 | |
| av. 80 | av. 130 | Neat cement. |
| — | 60 to 150 | 1 part sand to 1 part cement. |

The strength of mortar one week old, made of equal parts of improved cement and sand, averages about two-thirds the strength of the neat cement of the same age.

The two brands of improved cements above mentioned give very high tensile tests at the end of one year when mixed with 2 parts of sand ; in fact, they are nearly equal to the lower grades of Portland.

### TESTING.

Space will not permit of a detailed description of the methods employed in mixing the cement and putting it into the moulds, but a few lines will be devoted to enumerating the most important mechanical tests :

(1) *Checking* or *cracking*. Make four cakes or pats of neat cement about 2½ inches square and ⅜ inch thick, with thin edges; immerse two of these as soon as they have set, and the remaining two about one hour afterwards. Also make four pats with sand (1 to 1 for natural and 1 to 3 for Portland), and immerse these in the same manner. At the end of a week examine them for cracks, and crumble them with the fingers to ascertain their strength. Sometimes cements will be found which will not bear immersion immediately after setting, and such cements should not be allowed in work under water.

(2) *Tensile strength*. Make 6 to 10 neat briquettes, one-half for 24-hour tests, and one-half for 7-day tests. The absolute strength of the cement at 24 hours is not important except on wet work, but the comparison between the 24-hour and the 7-day tests is valuable, as before explained. Also make four or more briquettes with sand (1 to 1 for natural and 3 to 1 for Portland) for 7-day tests. Some cements which will not pass the neat test will give very good results when mixed with sand: others, again, give quite opposite results, so that no idea can be formed from the neat tests as to what the action will be when mixed with sand.

In conclusion, the writer wishes to call attention to the results of tests of Canadian cements as given in Mr. F. M. Bowman's paper, published in the last Proceedings of this Society. From these figures it would appear that the average tensile strength of Canadian cements (Napanee, Thorold, and Queenston) is about 40 pounds at 7 days and 80 lbs. at 30 days.

Judging from the analysis given of Napanee cement,

| | |
|---|---|
| Silicic acid - - - - - | 28.43 |
| Alumina - - - - - | 10.50 |
| Lime - - - - - - | 43.05 |
| Magnesia - - - - - | 18.02 |
| | 100.00 |

it would appear that a much better cement should be made. The magnesia, lime, and alumina are not in excess of the silicic acid, so that no free lime or magnesia should be present. The writer has tested samples of cement containing over 28 per cent. magnesia, and in which the amount of silicic acid was not sufficient to form a triple silicate by about 5 per cent.; yet these samples broke at over 70 pounds at the age of 7 days. The 24-hour test, however, was nearly as high as the 7-day, showing that the cement was unsound. If engineers in Canada would specify and demand a cement giving good tests for all important works, the manufacturers would, without doubt, find a means of supplying it.

BATAVIA, N.Y., February 11th, 1891.

# TECHNICAL EDUCATION.

An address delivered by Professor Galbraith at the opening of the Engineering Laboratory of the School of Practical Science, February 24, 1892:

*Mr. Chairman, Ladies, and Gentlemen*,—The subject of the paper which I propose to read this evening is "Technical Education."

In selecting this subject, I was influenced not only by its appropriateness to the occasion, but also by the fact, as it appears to me, that there is more or less vagueness in the public mind as to its objects and methods.

The word technical is derived from the Greek τέχνη, an art, handicraft, or trade. The idea involved in this word is the bringing forth or making of material things, as distinguished from thoughts and mental images. It is not always safe, as you know, to infer the modern meaning of a word from its derivation. Nevertheless it happens that one of the great branches of technical education, as at present understood, is exactly defined by the old Greek word, namely, the training of apprentices in the arts and handicrafts. Technical education in this sense has been in existence since the days of Tubal Cain, the instructor of every artificer in brass and iron; and to it we owe the greater part of the material progress which has been made since the world began.

In these latter days, however, a new application has been found for the term. In consequence of the growing competition for trade among civilized nations, and the recognition of the relations of art and science to production, schools for giving artistic and scientific training to those engaged in industrial pursuits are becoming acknowledged as one of the necessities of modern times. These are known as technical art schools and technical science schools. It is to the latter alone that I propose to direct your attention this evening.

From the time of the revival of learning in the middle ages down to the present century, the energies of the universities and schools have been directed in channels having little or no connection with the material necessities of civilized beings. The sole exception has been the schools of medicine. That this should have been so may seem strange, but it appears to me that we have not far go for the explanation.

The universities and schools are not the originators of knowledge. They are simply collectors and distributors. Natural science is a thing of modern growth. It had to reach a certain stage of development before the community could become interested in it ; and not until a demand for scientific knowledge had been created could it be admitted into schools of learning. How long, for example, is it since the physical sciences have been made a part of our Ontario school curriculum ?

Herbert Spencer, in an essay on Education, says :—"That which our school courses leave almost entirely out we thus find to be that which most nearly concerns the business of life—all our industries would cease were it not for that information which men begin to acquire as they best may after their education is said to be finished. And were it not for this information, that has been from age to age accumulated and spread by unofficial means, these industries would never have existed. Had there been no teaching but such as is given in our public schools, England would now be what it was in feudal times. That increasing acquaintance with the laws of phenomena which has through successive ages enabled us to subjugate nature to our needs, and in these days gives the common laborer comforts which, a few centuries ago, kings could not purchase, is scarcely in any degree owed to the appointed means of instructing our youth. The vital knowledge, that by which we have grown as a nation to what we are and which now underlies our whole existence, is a knowledge that has got itself taught in nooks and corners, while the ordained agencies for teaching have been mumbling little else but dead formulas."

It seems to me that these words of Spencer should be taken rather as an indictment of the community than of the schools. There has been, and may yet be to some extent, opposition on the part of men, permeated with the older culture, to the introduction of physical sciences into the schools, but this opposition is disappearing as the sciences grow and prove their fitness for a place in the educational system.

One of the main obstacles to the introduction of the teaching of science, even after its importance had been fully recognized, was the large outlay required for the necessary apparatus. Scientific investigation is both qualitative and quantitative. The teaching of science on the qualitative side consists in the enunciation and illustration of principles. The apparatus required for this purpose is comparatively inexpensive, and may be improvised to a great extent by the teacher. In many cases no apparatus at all is required—simple observation of natural phenomena being sufficient. The case is altogether different when the principles of science are to be investigated quantitatively. Instruments for making precise observations and measurements must be used. These instruments are expensive, and cannot be made by teacher or student. The highest mechanical skill is required for their manufacture, and patience, time, and opportunity for their use. Laboratories have to be equipped, and the whole time of teacher and student given up to work with the hand, eye, and ear.

It is not to be wondered at that the introduction of science into the curriculum has been slow. Now that it has been accomplished, the question naturally arises, Wherein exists the special necessity for the establishment of technical scientific schools? I think it may be answered thus:

In all schools for the teaching of professions and callings, whether we choose to consider them technical or not, it is an admitted necessity that the teachers should be practical men in such professions and occupations. What would be thought of a medical school in which the teachers were not physicians? of a law or divinity school in which they were not lawyers and theologians? In like manner, the teachers in technical schools should be engineers, architects, manufacturers, artisans, miners, and agriculturists, if it is possible to get them. The difficulty which exists at present to a large extent, but which will disappear with the progress of technical education, is that there are very few men in the above professions and occupations who have had a sufficient training in science to make them successful teachers—their knowledge is practical, not scientific. The teacher in a technical school should be more or less acquainted with the various trades—with the methods in vogue for handling and transforming material. He should know how things are done and made in actual life and on the commercial scale He ought to have a better perspective, so to speak, than the purely scientific man in reference to the needs of his students, and should be able to meet them more nearly on their own plane, and interest them in science by selecting his illustrations from their work, actual or prospective. It is of the first importance that he should keep himself informed in the latest manufacturing processes. This cannot be done by reading. The text-books are always years behind the times in this respect. Manufacturing and engineering periodicals are better, but still they convey little or no idea of the scale on which work is done. Personal observation, travel, and engaging in outside work whenever possible are the only methods whereby the teachers in technical schools can gather the proper material for illustrating scientific principles and maintaining the interest of students in their work.

The principal work of a technical school is the teaching of science, and not, as many suppose, to turn out fully fledged engineers, architects, manufacturers, and tradesmen; all that it can pretend to do is to turn out partially educated men. The graduates must supplement the work in the school by practical experience in after life before they acquire the right to call themselves practical men.

The practical work of the school differs in many respects from the practical work of actual life. Where it is work of the same kind, as, for instance, drawing, designing, the use of surveying instruments, lathework, smithwork, etc , yet the feeling of reality and responsibility is lacking. It is a very different thing to make mistakes in school work from making mistakes in similar work in actual life. A man is vastly more impressed by the necessary punishment which follows mistakes in the serious business of life than he can be by the arbitrary penalties instituted by the faculty.

Again, there is a great body of knowledge necessary to complete a man's practical education which it would be only an utter loss of time to attempt to give in a school, simply because there are no well-defined threads of scientific thought upon which to string it. Three-quarters of the information to be found in an engineer's handbook would be useless in the curriculum, although all-important in practice. Such knowledge becomes useful only when impressed by experience.

The establishment of engineering laboratories marks a new departure in technical education. Surely it will be said that the work in these laboratories is practical. So it is, but not perhaps in the sense in which the question is put. The steam engine in an engineering laboratory is not used for the same purpose as the factory engine. In the shop it is used for manufacturing purposes; it is placed in the laboratory for the purpose of being experimented upon. In the laboratory it is tried at different speeds, worked condensing and non-condensing, with varying steam pressures, with and without steam-jacketing, with different amounts of lead and cushioning, with different counterbalances for crank and connecting-rod, with varying clearances, with simple and multiple expansion. The work done at the main shaft is accurately measured: likewise the work in the cylinder—the feed water and condensing water are weighed—the degree of dryness of the steam determined. In short, in the laboratory all the conditions which may affect actual practice are experimentally investigated. It is only in this way that the principles governing the construction and action of engines can be fully determined.

What would an employer do with a man who should attempt any such work with the factory engine? He would simply give him to understand that his usefulness was gone, and that he had better look for employment at the School of Practical Science.

Again, since the teaching of principles is the main object of a school of applied science, it seldom happens to be useful to complete any of what is ordinarily called practical work, as would be necessary in actual life. To do so would occupy too much time. Practical constructions involve so many and various considerations and methods that the attempt to complete them would simply be reverting to the old state of affairs, when the apprentice gained his knowledge altogether on actual work. The study of the sciences would be so much interrupted and confused by such a method as to be of very little value. The practical work of a technical school, in so far as it is of the same kind as that of after life, must be selected and pursued rather as illustrating the principles of the special science under consideration than for the sake of the work itself.

In practical life, on the other hand, the result is the thing aimed at, and it matters nothing to those who pay for this result how it was arrived at, whether by rule of thumb or by the application of scientific principles. The work of the school is more analytic than synthetic, more destructive than constructive. The student pulls, as it were, machines to pieces in order that in after life he may learn to put them together. His proper work is investigation and experiment. After he graduates, his work, on the contrary, is construction and design. It would not be advisable to give equal prominence to both kinds of work in the school. The time is too short, and the feeling of responsibility which should govern construction and design is absent and cannot be artificially excited. Make-believe work is essentially false and unscientific.

The arrangement of the courses of study in the School of Practical Science is in accordance with these principles. The departments of instruction are civil, mining, sanitary, mechanical, and electrical engineering —architecture, analytical and applied chemistry, and mineralogy and geology.

In addition to the instruction given in the school, the students take such work in the University of Toronto as is necessary. The University work is mathematics, physics, and chemistry. Up to the present session mineralogy and geology have also been taken in the University. The greater part of this work will henceforth be taken in the school.

Through the exertions of the Hon. the Minister of Education and the liberality of the Provincial Legislature, an engineering laboratory has been established, and is now approaching completion. The Dominion Government have also contributed their quota by relieving the school from the payment of customs duties on such apparatus and machinery as it was found necessary to import from abroad.

It may be of interest to you to have a short description of the main features of this laboratory.

It consists of three departments: First, the department for testing materials of construction. Second, the department for investigating the principles governing the applications of power. This department is subdivided into the steam laboratory, the hydraulic laboratory, and the electrical laboratory.

The third department may be termed a geodetic and astronomical laboratory, as the work to be done in it, which relates principally to standards of length and time, is of special importance in these sciences.

In order to prepare specimens for the testing machines, a shop has been fitted up with a number of high-class machine tools specially suited for reducing the specimens to the requisite shapes and dimensions with a minimum of hard labor. It is also fitted with the necessary appliances for making ordinary repairs.

The machines in the department for testing materials are the following:

An Emery 50-ton machine built by Wm. Sellers & Co., of Philadelphia, for making tests in tension and compression.

A Riehle 100-ton machine for making tests in tension, compression, shearing, and cross-breaking. It will take in posts twelve feet long and beams up to eighteen feet in length.

An Olsen torsion machine for testing the strength and elasticity of shafting. This machine will twist shafts up to sixteen feet in length and two inches in diameter.

The last machine in this department is a Riehle 2,000 lbs. cement testing machine. The cement testing laboratory is fitted with the usual accessories.

These machines are all of the latest and most improved designs, and, with the exception of the cement machine, there are at present no duplicates of them in existence.

In the power department there are under the division steam two boilers, a Babcock & Wilcox 52 horse-power and a Harrison-Wharton 12 horse-power boiler. The engine is a 50 horse-power Brown automatic cut-off engine, built by the Polson Iron Works Co., Toronto, specially for experimental purposes. It is steam-jacketed and has three alternative exhausts, to the open air, to a jet condenser, and to a Wheeler surface condenser, kindly presented to the school by Mr. F. M. Wheeler, of New York, the inventor. There are also a Blake circulating pump, a Knowles air pump, and a Blake feed pump, the latter of which was a gift from the manufacturers. The engine is arranged so that it may be compounded when there are funds for the purpose. To have built the engine compound in the first place was deemed inadvisable, as the money was urgently needed for other work.

A machine now being constructed by the Riehle Bros., of Philadelphia, for measuring journal friction and testing lubricants, will shortly be placed in position. It is fitted with an ordinary railway car journal and box. The maximum loads occurring in practice can be applied. The maximum speed will be 50 miles an hour. This machine is expected to be an improvement upon any yet built for a similar purpose. I received a letter a few days ago from a railway in the Western States which intends to order one if we give a satisfactory report.

The hydraulic division of the laboratory is furnished with a three throw pump with double acting cylinders, built specially for the school by Northey & Co., of Toronto. It has adjustable strokes, and has a maximum capacity of half a million gallons per day. It has been designed to produce an extremely steady pressure, this being requisite for hydraulic experiments. The maximum head under which it works is 230 feet. There will be practically no addition to the running expenses of the laboratory due to the working of this pump, as the same water will be used over and over again, and the power will be furnished by the experimental engine. In order to make engine experiments the coal has to be burned in any case, and the necessary resistance supplied either by a brake or otherwise. Driving the pump is one method of doing this. A three feet turbine wheel of the jet type, built by the Fensom Elevator Co., of Toronto, forms a part of the same equipment. The pump furnishes the power for this wheel. There are two large tanks, built by the Doty Engine Co., of Toronto, for experiments on the discharge of water through orifices and over weirs.

The above apparatus is arranged with a view to testing water meters, measuring the discharge of fire streams and various other hydraulic investigations within the capacity of the plant.

The electrical division of the laboratory is equipped with the following dynamos :

Edison, Ball, Thomson-Houston, two Gülcher machines and a Westinghouse alternator with transformers, a Crocker-Wheeler, and a Kay motor, also two small fan motors.

There are in connection with it a Roberts storage battery, a gravity primary battary, and a fair equipment of lamps, arc and incandescent, of different types.

The power department is equipped with the usual measuring instruments, indicators, gauges, gauge-testing apparatus, scales, brakes, dynamometers, ammeters, voltmeters, resistances, galvanometers, etc.

In the geodetic and astronomical department are 100 feet and 66 feet standard of length, a 10 feet Rogers comparator with graduating attachment, a Howard astronomical clock and electro-chronograph, a Troughton & Simms 10-inch theodolite, and all the ordinary surveying instruments.

That you may not leave this building to-night under the mistaken impression that our equipment is complete, and that we can spend no more money, I propose to conclude this paper by touching upon some of our most pressing wants.

The department of architecture has recently been established, and is provided with a good collection of photographs and drawings. A large number of casts, models, and plates will be required, however, to complete the equipment.

The oldest laboratory in the school is that in the department of analytical and applied chemistry. It it well equipped for general work in qualitative and quantitative analysis ; also for the quantitative analysis of food, air, water, fuels, and illuminating gas. Special apparatus is now urgently needed for the analysis of iron, steel, and other materials of construction, to supplement the testing work of the engineering laboratory.

The important department of mineralogy, assaying, and mining has at present a very meagre laboratory equipment. In view of the interest which is now being taken in Canadian mining, it is to be hoped that this state of affairs will be immediately improved, and that the School of Practical Science may be enabled during the next session to offer to those who may desire it a complete course of instruction in mining engineering and metallurgy.

In sanitary engineering we have at present no special laboratory. Our hydraulic plant can be utilized largely in connection with this department, but in addition a collection of models is very necessary for purposes of illustration.

As cities increase and population grows denser, sanitary problems become more complicated, and have to be dealt with by communities and governments instead of depending on individual action. As a consequence, sanitary engineering is becoming a most important branch of the profession, and a prominent position should be assigned to it in the curriculum of a technical school.

The rapid development of electrical lighting is bringing into prominence the question of the measurement of the illuminating power of electric lights. Special difficulties surround this problem, and it is desirable that our electrical laboratory should be furnished with the means for making such investigations.

It would greatly facilitate the work of the school in all departments to have means for making photographic lantern slides. Ordinary charts and maps soon grow out of date, and take up a large amount of room. A photographic outfit would give the means of making lantern slides of all the latest illustrations of machinery and construction that are published in engineering, manufacturing, and architectural journals, and of exhibiting them to large classes.

Another pressing want is a good technical library. If it were not for our periodicals, we should have no library at all : and while the Toronto

Public Library has a good collection of works on technical subjects, yet they are, for all practical purposes, beyond the reach of our students.

Collections of rocks, minerals, and products illustrating various stages of manufacturing are very much needed in the departments of mining and applied chemistry.

In view of these pressing demands the question will naturally arise, What is to be the outcome of this technical education—where are the young men to find employment? If the country cannot support them, what justification can there be for the expenditure? It seems to me that this is a question in political economy, and might properly be referred to the distinguished head of that department in the University of Toronto or to our friends the Trades and Labor Council.

My answer can only be vague and general. I would reply by asking why we have gone into debt for the purpose of building canals and railways, docks and harbors—why have we built expensive houses of parliament, churches and jails, sewers and water works, colleges and poorhouses? Is it not because we feel that we are as good as our brothers across the sea or as our cousins south of the lakes—are we not a civilized people, and have we not a right to these luxuries whether we can pay for them or not? Is it not as useful to the country to turn out men educated as engineers, architects, mechanics, miners, and farmers as to turn out lawyers, doctors, ministers, and bankers? Will not the graduates of our technical schools have that very education which our mechanics, artisans, and tradesmen of all classes most desire, and of the necessity for which they are reminded every hour? If you had seen with me the crowd of eager men, young and old, who assembled the other evening at the opening of the Toronto Technical School, you would no longer have any doubt as to the desirability and necessity of technical education. If the country cannot support such men, so much the worse for the country, and so much the better for that country in which they find employment.

If we are ever to pay off our foreign debt and trade on equal terms with other nations, we must develop our material resources with economy and skill, and among the means making towards this end not the least promising is Technical Education.

# EXTRACTS FROM LETTERS READ BEFORE THE SOCIETY.

## BRIDGEWORK.

By Mr. F. M. Bowman,

*Bridge Department, Pennsylvania Steel Co., Steelton, Pa., December 31st, 1891.*

*Mr. President and Gentlemen*,—It may not be amiss to give you a few ideas that have occurred to me during my connection with bridgework. The greatest difficulty to the young graduate intending to take up this branch of engineering is to get a start. This, of course, is a difficulty in all branches, but it seems to be peculiarly present in the case of bridgework. In other branches the trouble generally lies in the supply being greater than the demand, and very often experienced men are as unable to secure employment as the less experienced. But it is different with bridgework. Almost every issue of the *Engineering News* contains advertisements for experienced bridge designers and draughtsmen, while the contra advertisements of such men seeking employment are not so numerous.

Having made it clear, then, that securing initial employment is the one great obstacle of the beginner, I shall now state some methods which have been adopted to overcome this difficulty. The method which meets with least success is that of applying by letter. Such a letter may or may not be answered, but in either case it is filed away, and in the case of the uninitiated (the one under consideration) it is never referred to again. If, through some friend or otherwise, an engagement can be made at a nominal salary, it is wise to make it, trusting to ability to secure a speedy advancement. In other cases, again, men are often successful by applying personally. This is probably the best way of ensuring success. Again, I have known several young graduates of the best American engineering schools to secure the work of blue-printer or some like position, and with the opportunities thus afforded were soon advanced. Some companies, such as G. W. G. Ferris & Co., of Pittsburg, Pa., make special arrangements with young graduates to give a fixed salary to those who contract to stay with them for two years or so; the company, on their part, agreeing not only to expound the mysteries of the bridge, but also to assist in securing for their employee a good position after the two years have expired.

It is necessary to work for at least two years as a bridge draughtsman in order to become thoroughly familiar with all details and connections, so that one may know how to arrange, to the best advantage, the details of his design. The work of these years is, of course, very hard and tedious, and one becomes eager to get into the higher positions of designing, estimating, inspecting, and testing. During this interval, however, he becomes a good draughtsman, and at the same time has no inconsiderable experience in the other lines.

In view of the fact that each engineer has his own methods and each company its own apparatus and equipments, I think it is advisable for the younger engineer to change employers at intervals in order to have the advantage of the methods and equipage of each. This may be slightly detrimental from a financial point of view at first, but the first cost is made up for in the end.

## CIVIL ENGINEERING (INCLUDING MINING ENGINEERING).

By H. E. T. Haultain.

* * * * * * * * * * * * *

All the subjects included in the departments of "Civil Engineering (including Mining Engineering)" and "Mechanical and Electrical Engineering" *ought* to be studied by the mining engineer, and much of the departments of "Architecture" and "Analytical" and applied "Chemistry," and of course all of "Assaying and Mining Geology," besides the subjects ore-winning and ore-treating, the latter of which is an especially large and heavy subject.

Let us consider what is expected of the mining engineer, considering the term "mining engineer" to mean the man employed for the designing of the whole plant, and not the one individual man in charge.

Let us commence at the end, when all the work has been done. Consider a fairly large mine in one of the new countries, where a few years ago it was all a wilderness. What have we? A mine containing several miles of shafts, adits, winzes, galleries, rises, drives, etc., etc., out of which is being blasted and raised to the surface 500 or more tons of rock-matter daily. This 500 tons of rock-matter has to be brought into the condition of fine sand, and has to pass through various and complicated processes to free the pure mineral or minerals from each other, and from waste products, and then, in all probability, the separated mineral has to go through several chemical processes, equally varied and complicated, to obtain the metal or metals before it leaves the mine.

Underground are required air compressors and drills, ventilators, miles of tramways worked by animal power perhaps, (but very soon to be worked by electricity,) hoisting machinery, both for raising this 500 tons and also for lowering and raising several hundred men to and from a depth of 500 to 1000 feet or more.*

Pumps also will certainly be required, perhaps to pump 1000 gallons a minute to a height of 500 feet. All this will require 300 horse power or more, which must be supplied by steam or water power in connection with electricity. On the surface a small system of railways will be required to carry the different products to the different places. The ore has to be crushed and then stamped, and then put through the various washing processes to free it from the waste stuff, all of which means a great deal of machinery, requiring at least 500 horse power. Then come the smelting processes, which form a department of themselves, but which come under the head of the general term "Mining Engineering." Thus we require at least 800 horse power, and this must be supplied by steam or water power. If there is no coal mine near, or if wood is not over-plentiful or cheap, then if water power can be had within 20 miles, it would be best to use the water power and electricity. This entails a good deal of hydraulic work, dams, canals, sluices, etc. To keep all this in order are required machine shops, carpenter shops, smithies, and a sawmill, etc., and to work the whole affair there may be 1000 men or more, with, say, 2000 depending on them, and all these have to be housed; this, and much more, comes into the work of the mining engineer.

The mining engineer has had to know all about the geology of the place before sinking his shafts and driving his adits. He has to erect houses for his work and his men, and shops and mills to supply his materials. If electricity is not used, steam engines of all kinds will be required for hauling, hoisting, pumping, air compressing, locomotives, and for driving general machinery; he has to erect these, and, in all probability, to teach his men how to use and look after them; he has an air-compression system to devise, and erect besides systems of haulage and of ventilation. On the surface, all his buildings to design and erect, and a system of tram-lines to design, overhead or otherwise, and his crushing and stamping mills, his sieves and separators, and pigs and puddles, and shaking-tables, and concentrators of all kinds and descriptions. If it is gold he is after, he requires amalgamators and chlorination plant, etc., etc., *ad libitum*. Then there are the smelting furnaces and all that belongs to that department in the shape of furnaces, both reverberatory and blast, for roasting, smelting, and refining. Then all the shops, smithies, and storehouses, and the whole place has to be lighted. There is a young town to build, and drainage to look after, besides roads, bridges, dams, canals, and sluices for his water power. If he is going to have electricity, the mining engineer has to design and erect his electric plant, and teach his men how to look after it, and, above all, he has to manage 1000 men or more on the minimum of wages, by no means an easy thing in these days of agitators and strikes; while above and beyond all, he has his directors in London to humor and satisfy.

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*The deepest mines in the world are in Pzribrain in Bohemia.

This is a rough outline of part of the work of the mining engineer. He may also be expected to undertake geological surveys, or to report on new mining districts, which means geology, mineralogy, paleontology, etc., in no small measure. Then there are mining engineers for coal, which is a branch entirely separate from metalliferous mining, and yet "Civil Engineering (including Mining Engineering)."

* * * * * * * * *

Young students in the commencement of their studies, as they see in the outside world more and more of what is expected of the engineer in actual work, when they see bridges, and railways, and machinery being constructed, and consider that they will be called upon to do the same sort of thing, begin to ask when and where they are going to learn how to do this; this, which, being the most prominent result of engineering work, fills up their idea of engineering. They are anxious to be doing this kind of thing, and are apt to get uneasy at so much time being spent upon Algebra, and Euclid, and Conic sections, and such like mathematical speculations, especially when they see the "practical" side of the question handed over to the uncertainties of "vacation notes." And so does one, on first looking at it, wonder how Civil Engineering, in contradistinction to mechanical and other engineering, is going to include Mining Engineering, and, still more, how any building within four walls can pretend to teach engineering, be it civil, or mechanical, or mining—to teach men in three short years of seven months each to cope with all the various forms and conditions of nature in ways and means suitable to the conditions and requirements of modern circumstances. But does any institution in the world pretend to teach engineering "practice" in its entirety? No; it cannot.

Facts and formulæ, methods of nature and methods of reasoning, are taught: but methods of practice are left almost entirely to be learned in actual work. With the main exceptions of surveying and draughting, in which the school has a very thorough course in both theory and practice, there is very little of actual office or field work attempted. This is only as it must be.

Before we learn methods of practice, we ought to learn methods of reasoning; if we have our methods of reasoning, the methods of practice follow easily and quickly.

We can divide the engineer's field of study into three divisions: (1) Methods of nature, including facts which may hardly be said to be methods, *e.g.*, the three angles of a triangle are equal to two right angles. Under this heading I would include all the laws of Chemistry, Optics, Hydrostatics, Dynamics, and Mechanics, etc., and nature's methods as shown in Mineralogy, Geology, etc., and also the facts of geometry, and those facts connected with the peculiarities of substances—such as, iron can sustain a tension of so many pounds to the inch.

(2) Methods of reasoning, both in connection with the methods of nature, as in the theory of internal stress; also methods of reasoning, pure and simple, which in themselves are of no ultimate value beyond mental training, but which form foundations and steps for further reasoning, as in algebra.

(3) Methods of practical dealing with the methods of nature, methods of practice in turning the methods of nature to our use, *e.g.*, turning the energy of the combustion of coal into a form convenient for use, as in the steam engine or gas engine; the application in the construction of a bridge of the power of iron to resist stress, and of the facts of geometry, and the theory of mechanics, together with a consideration of all the circumstances surrounding both the present construction and the future life of the bridge.

The school training of an engineering student consists chiefly in Nos. 1 and 2, and in preparing him to pursue his studies in No. 3.

We have the difference between the so-called "theoretical man" and "practical man." The man who is only practical and sneers at the theoretical man is only in No. 3, and knows very little of Nos. 1 and 2. But it is self-evident how extremely more practical the theoretically trained man can be when he has his methods of practice.

The engineering student's chief work should be in the training of his mind; the training of the mind in methods of reasoning, thought, and observation. Consequently do not fret because you will not be able to build a "Forth" bridge on graduating, but devote yourself to this training of your minds.

The main thing, I believe, consists in the training of the mind; quickness, clearness, and accuracy are what must be aimed at. The mind can be trained to quickness and clearness in reasoning most successfully in abstract reasonings, pure and simple; so algebra and Euclid serve two purposes: not only are they methods of reasoning and the foundation for further methods, but they form a splendid gymnasium for the training of the mind.

There are two functions of the brain which are most valuable, and which the course at the school, together with the Engineering Society, particularly help—I mean reading and observation. It is by means of these two that the student is going to advance himself in the division No. 3. It is in the observing of actual work, and in the reading about work done, that the student has the means of learning methods of practice. The student, after graduating, requires to be employed on actual work.

Consequently these subjects require careful and studious attention, as they will be the immediate means of further advance. Having got employment, read and observe, and assimilate what you read and observe. You know the word assimilate? When a substance is assimilated, it is not only digested, but becomes an intimate part of the animal assimilating it. Don't imagine, by any means, that your course is finished on graduating. Not at all; you have still *everything* to learn; but you are in a position to learn it. You have been taught nature's methods; you have been taught to think, to observe, and to read. You have been taught enough of methods of practice to make yourself thoroughly useful to your employer, and your duty is to learn methods of practice, methods of dealing with nature as found most suitable to modern circumstances.

A word, before closing, about mining methods. In speaking of the work done by the mining engineer, I did by no means mean that all the work described would have to be done by one man; that would be a practical impossibility. In actual work, the greater part of the designing of the appliances would, in all probability, be done by Frazer and Chalmers, of Chicago, New York, Denver, Lima, Tokio, Johannesburg, London, and other places, the chief makers of mining machinery.

The mining engineer in charge of the work would find out what he wanted and give the outline of the general design to this or some other manufacturing company, and would leave all details to them, unless he were a specialist in some particular branch.

The designing of the appliances belongs to the general department of Mining Engineering, and consequently I used the term mining engineer to represent the person or persons employed on the designing of the whole plant. If there were much electricity in connection with the mine, there ought to be a specialist, a mining electrician, as also a specialist for the smelting and assaying, and the same in other departments.

We find that in considering the general subject of Mining Engineering under the three heads mentioned, that under No. 1 there are some special methods of nature to be studied—mineralogy, geology, and kindred subjects, in addition to the subjects studied for Civil Engineering only; that under No. 2 the methods of reasoning are the same both for Mining and Civil Engineering. Thus we see that the course in Civil Engineering, when it includes Mineralogy, Geology, assaying, and some ore-dressing, can quite consistently include Mining Engineering; though, perhaps, it would be better if the mining student *could get a little more mechanical work than is generally included in the ordinary Civil Engineering course.*

I believe *every* engineer should have a *fair knowledge of electricity.*

London, England, August, 1891.

# NOTES AND COMMENTS.

This session has witnessed a number of renovations and changes in the working of the Society.

Among some of its undertakings may be cited the supplying of two or three grades of egg-shell drafting paper, cut to standard size. This is a great saving of inconvenience, labor, and expense to the students who, although not members of the Society, have the privilege of obtaining this paper at practically cost price. This alone should induce *all* students to become members; for, leaving out of consideration the great benefits derived from attendance at meetings and the discussion of practical questions closely connected with their work, the matter of expense alone leaves no doubt as to the relative costs of each side.

Another innovation, of perhaps minor importance, was the selection and purchasing of school colors by the Society. Although not exactly pertaining to the aims and objects of our body, yet being the principal organization of the school, and matters of this nature being better done by an organization than by any other means, it was taken in hand, and has been very satisfactorily performed. The colors are at once unique and distinct, and characteristic of the school shield, which bears the colors, blue, gold, and white.

The establishment of the Fourth year, which was looked forward to with great interest by the students, is now a thing of reality.

While at present no degree is connected with it, it has been practically promised and therefore virtually secured. The diploma already given with graduation must not be belittled; but it is conceded that a degree bears more weight and is of greater value. The degree in question is not one which may be tacked on indiscriminately by almost any one with a little engineering practice, as the letters C. E. often are, and therefore in that respect is perhaps of higher grade.

The work of the Fourth year student consists chiefly in testing and experimenting with the material, machines, and instruments placed in the Laboratory for his use. This Laboratory is well equipped with all the necessary machinery, etc., requisite for thorough tests and experiments in almost every branch of engineering.

An exchange in pamphlets with the Engineering Society of Ann Arbor University, Michigan, was made in the early part of this session. Their annual is entitled the "Technic," containing matter well and clearly written. Having about 100 pages of varied subjects, it serves the purpose of a very instructive text book, and also as a book of reference. Electricity, Architectural Engineering, and Mathematics of Least Squares, all receive a thorough and intelligent consideration; nothing of practical importance being untouched.

We are also indebted to the Provincial Land Surveyors for their exchange: "The Proceedings of the Provincial Land Surveyors of Ontario." It is a publication containing much useful information to the intending P. L. S., giving at once clear and concise descriptions of operations and works connected with surveying, which prove of great assistance to the comparatively inexperienced practiser, and serve as a reliable source of information upon which to base similar operations or structures.

In the "Extracts from Mr. H. E. T. Haultain's Letter," a somewhat detailed description of the duties of the Mining Engineer is given. It conveys the impression that mining engineering should be a distinct and complete course of itself, and although at present we have it combined or included in civil engineering, yet the practical work in both is to a great extent of distinctive character. It would also appear from his description that the civil, mechanical, and electrical were included or were, at least, very requisite in the location, management, and operation of a mine and its varied machinery, etc.

In two or three of our previous numbers we are indebted to Mr. Haultain for some very excellent and practical papers and letters on his own work. Much interest is excited and much instruction derived from communications of this nature. It is to be hoped that many of the other graduates, who have not yet done so, may favor us with something similar; for the experience of those graduating from the school proves interesting to a greater extent than papers wholly prepared from compilation or reading. To those who hope to follow in footsteps of the graduates, nothing of the outside practice is more closely connected with them and their work than the experience of those who have so closely preceded them.

No. 6 1892-3

# PAPERS

READ BEFORE THE

# ENGINEERING SOCIETY

OF THE

## SCHOOL OF PRACTICAL SCIENCE

TORONTO

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# PREFACE.

The Engineering Society of the School of Practical Science was organized in the spring of the year 1885 by the students in the Department of Engineering of that year, assisted by Professor Galbraith.

Since that time the usefulness, size, and importance of the Society has been steadily increasing.

Meetings are held every alternate Wednesday in the academic year, when papers relating to engineering matters are read and discussed.

Up to the present time, our annual pamphlet has been published during the second term. Last session, however, it was decided to leave the publication of each year's papers over till the beginning of the following year. While this makes no material difference in the pamphlet, it gives more time to the committee to get the papers and advertising matter ready for the printers—a convenience which those connected with such work can well-appreciate.

The papers in the present number have been contributed chiefly by students and graduates of the school.

The thanks of the Society are due especially to those graduates and other members of the engineering profession who have favored the Society with papers during the past year, and we trust that their example may be followed by others. Papers from men in actual practice are of special interest and value to students.

While the papers in this pamphlet are read and discussed chiefly for the benefit of students, yet it is hoped that they may be not uninteresting to the profession at large.

The present edition consists of 1,000 copies, which will be widely circulated amongst engineers and those of allied professions.

DECEMBER, 1893.

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# ENGINEERING SOCIETY

OF

# The School of Practical Science

TORONTO.

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## PRESIDENT'S ADDRESS.

Gentlemen,—As this is not our first meeting I cannot open, as is customary, by bidding you welcome to another year of the Society's work. As most of you know, the president was duly elected last spring; but as he has left us for other spheres of labor, for a while his office was vacant, which vacancy you have seen fit to appoint me to fill. When I think of the ability and fluent speech of the gentleman I am called upon to replace, and when I remember those who have presided over these meetings for the past three years, I am made to feel my own incompetency and want of experience, and particularly does a consideration of the present importance and development of the Society force this upon me; so I feel that I have good reason to be grateful to you, gentlemen, for your expression of confidence in appointing me to this office, and I assure you that I am fully awake to and thoroughly appreciate the honor you have conferred upon me.

You have chosen a committee which will, during the coming year, fully sustain the Society's usefulness, and in whose care its progress is safe.

But here, gentlemen, I wish to remind you of the reason for the existence of your committee; that your officers are appointed to attend to business details and to procure the even working of the Society's meetings, so that its members may be free to carry out the purposes for which it was organized.

I think there is a tendency to overlook the fact that it is the members that constitute the Society, and that it is only by their active participation in its affairs that its continuance is justified. Your officers you have selected to be your servants, and the well-being of the Society lies as much in your own care as in theirs. And surely, gentlemen, they who systematically give up a portion of their time for our interests may reasonably ask for that sense of support that is felt from the vigorous manifestation by each member of his close interest in the affairs of the Society.

It may seem to be an expression of confidence to accept the work of your committee without comment, but surely it is evident that such a course of action will not work for the good of the Society ; will be harmful to yourselves, in fostering a spirit of dependence and want of interest ; will cost you many a valuable chance of learning readiness of speech and facility of sensible criticism ; and will also be harmful to your officers, in encouraging hasty and careless work, and in diminishing their activity. I would, therefore, urge that each member would make a point of fully understanding the affairs of the society, make sure that full information is given upon every obscure matter, in the regular meetings, and see that no business pass without its rightful amount of discussion. Indeed, gentlemen, the progress of the Society will rest mainly with yourselves during the coming session. It is altogether too large a ball for your officers to keep rolling unaided. They only constitute its machinery. Its energy, its life, must come from you. I urge you, in your determination to make this year's meetings a success, and in your energetic interest and watchfulness, that you keep continually in advance of your committee, so that it may be encouraged in its labors, and roused to further efforts.

There are two good reasons for pressing this point upon you. In the first place, the Society has grown to proportions such that its affairs require careful handling. If you will consider how widely it is becoming known, the amount of money involved in its undertakings, and its rapid growth, you will be ready to admit that mistakes in its management may start a train of serious consequences, and, therefore, that your full knowledge and careful consideration will be needed. I have already mentioned the other reason, namely, the good to be gained by making use of the opportunities for speaking. Let me briefly remind you of this important matter. The time for our meetings is taken out of our regular working hours, and this means that these meetings are recognized by the Faculty as forming a part of the regular course—a necessary part of our education here. They do this in many ways, and as these are set out in the constitution, and in several numbers of our publications, I would refer you to these sources, and simply mention one item of our required accomplishments. In these days all professional men come to be concerned, sooner or later, with public meetings—in railway committees and boards; in civic committees; in various societies; in politics, perhaps. It is one of the tendencies of the time, and therefore it is advisable for us to learn the proper system of carrying on meetings, and to study the correct methods of procedure, while we are students and among friends. It may prove of greater value to us than we think, in our immediate future, that we have gained familiarity and readiness in the customs of public assemblies. And we have excellent opportunities for such practice; so let us endeavor to make full use of them. To do this we will require to be able to express our wishes or ideas in plain and simple language. We know that this art does not come readily to all, but it is a most needful accomplishment, and each one should spare himself no effort and heed no failure in his work to acquire it; for, like everything else, it is learned by successive attempts. I think we ought to look upon our Society as a field for doing practical work in these subjects, which are just as important to us as any other that we take up. It is said that the most important part of a man's education is that which he gains himself; and here, on these afternoons, the time is given to us for this very purpose of self-training. We are left to our own efforts.

This is taking a narrow view of the purposes of our Society, but I wish to confine myself to one or two contemporary matters.

There has now come about a tendency to separation between the four years that did not formerly exist, at least to the present extent. These meetings will give us an excellent counter-tendency, bringing us into better relations, and promoting a friendly knowledge of one another. Again, the four branches of the professions are now well established, introducing a division of a different nature—one that will affect the individual in his relation to his calling and general habits of mind, rather than the student body as a whole. We are compelled, more and more, to confine our attention to smaller regions in our work, becoming specialists, with the attendant risks of narrow sympathies and one-sided views. We are fully aware of the need of a wide general knowledge of engineering matters, as well as a narrow special one. But we have, as yet, hardly realized our power to limit our interests, to destroy our relish for the doings of our fellows, and to petrify us into a small daily routine, by the constant vigorous application of our energies along one channel. Now, here, while we are plastic, we can form habits of mind that will go far towards preserving us from the encroachments of this spirit of narrowness. If, in these meetings, we are accustomed to take an intelligent interest in and to discuss papers upon matters not belonging to our own chosen branch, it is very probable that the liberal-mindedness thus begun in us here will grow into a part of our mental furniture, and we shall see before us the possibility of becoming well-informed men as well as engineers.

Gentlemen, one of the objects of this Society is to give students the opportunity of reading a paper upon some subject of which they have practical knowledge, or in which they are interested. Let us remember this, that while we are grateful to and appreciate the kindness of those gentlemen who so often help us, yet one of the main objects of the Society is that we follow their example and write papers ourselves. The time will be well spent, the preparation itself is a valuable source of learning, and the information gathered will be of benefit to the Society ; and besides, apart from the subject-matter, the very processes of reading and discussion require practice, and will be of great benefit to you. It will be well, then, for you, by papers, to give yourself the chance of knowing what you can do, and where your faults lie, and your fellow-members the material upon which to exercise their attention and judgment, and the opportunity to practise discussion.

W. A. Lea.

# BRIDGE SPECIFICATIONS.

By T. Kennard Thomson, C.E.

The writer begs to submit some bridge specifications drawn up by himself last winter, with a few comments on the same, in hopes that they may prove of interest to our Society. It is hoped that these specifications will be thoroughly discussed by the members, for, as a rule, the discussion of papers is much more valuable than the papers themselves. Many members of the American Society of Civil Engineers read the discussion before the original articles. The writer will be only too glad to answer any questions or criticisms to the best of his ability, if the secretary will kindly advise him thereof.

These specifications are very much shorter than usual, as an attempt has been made to cut out much that is merely cumbersome. Bridge specifications are generally as lengthy, verbose, and vexatious as a lawyer's document. They are useless in the hands of the inexperienced, and too long for an expert.

## General Specification, Iron and Steel Bridges.

## PROPOSAL.

### BIDS.

1. Bidders will submit sealed proposals on the basis of so much per pound in the finished structure.

### CONTRACT.

2. It is understood that when a tender is submitted, the contractor agrees to be bound by these specifications, and by the stipulation in the letter of invitation as to the time of completion.

### PATENTS.

3, Should the contractor make use of any patented device, he shall protect the railroad company against any or all claims on account of the use of such patents.

## DRAWINGS.

### APPROVAL.

4. As soon as possible after the contract has been awarded, the contractor shall supply the engineer with a complete set of all stress sheets, working drawings, bills of material, and cards of all pins, bars, rods, etc.

No work shall be done until these have been approved in writing by the engineer, and after their approval no change shall be made except with his consent or direction in writing.

### DRAWINGS FOR FILE AND INSPECTORS.

5. Three complete sets of drawings, bills, and cards shall be furnished the engineer free of charge, two sets being for his file and one set for his inspectors.

6. All necessary dimensions shall be given by plain figures.

## GENERAL DESIGN.

7. Masonry plans for each bridge will be furnished by the engineer, and, unless otherwise stated, for bridges of:

80 feet span and under, plate girders will be used.

80 to 120 feet, lattice girders will be used.

120 feet and over, pin-connected trusses will be used.

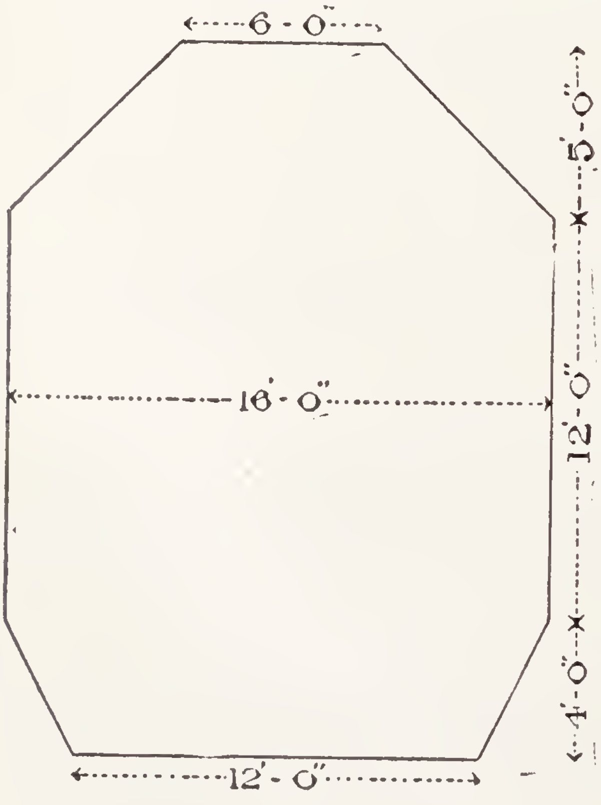

Fig. 1.

### SPACING OF TRACKS.

8. The distance from centre to centre of double tracks will be thirteen feet.

### CLEARANCE.

9. On a straight line a clear section as per diagram (Fig. 1) must be provided for single track bridges.

The width must be increased so as to allow the same minimum clearance when the bridge is on a curve or double-tracked.

10. Bridges on curves will have the outer rail elevated as follows :

For a 1° curve elevate the outer rail 1 inch.
" " 2° " " " " " 2 inches.
" " 3° " " " " " 3 inches.
" " 4° " " " " " 4 inches.
" " 5° " " " " " 4¾ inches.
" " 6° " " " " " 5½ inches.
" " 7° to 12° " " " " 6 inches.

### SPACING OF STRINGERS.

11. Deck girders and track stringers will generally be spaced not less than seven feet apart, centre to centre.

## CALCULATION.

### DEAD LOAD.

12. The dead load shall consist of the weight of the entire superstructure; the weight of the wooden ties, guard rails, and rails shall be assumed as 450 pounds per lineal foot of track.

13. Two-thirds of the dead load shall be considered as applied to the panel points of the chord supporting the floor, and one-third to the other chord.

### LIVE LOAD.

14. All plate girders and spans under eighty feet shall be designed to carry (in addition to the dead load) a live load of 4,000 pounds per foot, of which 136,000 pounds is liable to be concentrated on four axles thus:

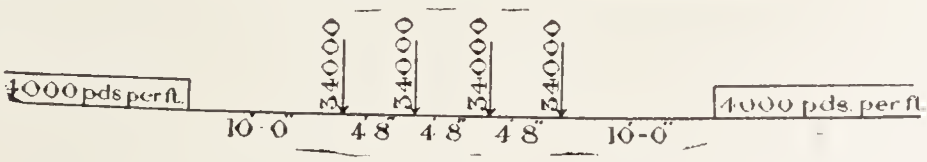

Fig. 2.

or 80,000 pounds to be concentrated on two axles thus: Fig. 3.

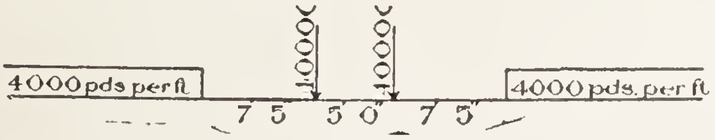

Fig. 3.

All trusses shall be designed (in addition to the dead load) for a uniform live load of 4,000 pounds per lineal foot of track, and also two concentrated loads of 20,000 pounds each, to be placed fifty feet apart.

### WIND.

15. The top and bottom lateral systems shall each be proportioned to resist a uniformly distributed lateral force of 150 pounds per lineal foot, and the lateral system nearest the floor shall (in addition to the above) be

proportioned for a moving lateral force of 300 pounds per lineal foot. For spans over 200 feet, add ten pounds per foot to each lateral system for every additional twenty-five feet of span.

### CENTRIFUGAL FORCE.

16. If the bridge is on a curve, the lateral bracing must be proportioned to resist (in addition to the wind stresses) a centrifugal force equal to three per cent. of the live load on all tracks for each degree of curvature.

### CO-EFFICIENT OF FRICTION.

17. The friction due to applying brakes shall be considered as equal to twenty per cent. of the live load.

18. Shipping weights shall in no case differ from the calculated weights by more than 2½ per cent.

## UNIT STRESSES.

### TENSION.

19. In tension members the unit stress caused by the dead and live loads shall in no case exceed the following:

### MATERIAL.

| | Stress per square inch | |
|---|---|---|
| | IRON. | STEEL. |
| For lateral | 15,000 | 18,000 |
| For "I" beams | 7,500 | 9,000 |
| For plate girder flanges (under 60′ span) | 8,000 | 9,500 |
| For plate girder flanges (60′ spans and over) | 8,000 | 10,000 |
| For lattice girders—bottom flanges | 8,000 | 9,500 |
| For bottom chords and main diagonal spans, under 150 feet—forged bars | 9,000 | 10,000 |
| For bottom chords and main diagonal spans, 150 feet and over—forged bars | 10,000 | 12,000 |
| For bottom chords and main diagonal spans, plates and shapes—forged bars | 8,000 | 9,500 |
| For counters and long verticals—forged bars | 8,000 | 9,500 |
| For counters and long verticals, plates and shapes | 6,500 | 7,500 |
| For floor beam hangers and similar members—forged bars | 6,000 | 7,000 |
| For floor beam hangers and similar members, plates and shapes | 5,000 | 6,000 |

20. Steel eyebars will be preferred.

### COMPRESSION.

21. In compression members the maximum allowable unit stress due to the dead and live loads shall be determined by the following formulæ :

| | IRON. | STEEL. |
|---|---|---|
| For two square ends, | $P = 9{,}000 - 30\, l/r$ | $P = 11{,}000 - 35\, l/r$ |
| For 1 square end, | $P = 9{,}000 - 35\, l/r$ | $P = 11{,}000 - 42\, l/r$ |
| For 2 pins ends, | $P = 9{,}000 - 40\, l/r$ | $P = 11{,}000 - 48\, l/r$ |
| For lateral struts, | $P = 12{,}000 - 50\, l/r$ | $P = 14{,}400 - 60\, l/r$ |

Where :—
$P$ allowable stress per square inch.
$l$ length of member in inches.
$r$ least radius of gyration in inches.

### COMBINED STRESSES.

22. The unit stress caused by the dead and live loads and wind and centrifugal forces combined shall not exceed the above limits by more than twenty-five per cent.

### ALTERNATE.

23. Members subject to alternate tensile and compressive stresses shall be proportioned for both kinds of stress. Each stress, however, shall be increased by an amount equal to $\frac{8}{10}$ of the other stress before determining the dimensions by the above unit stresses.

### TRANSVERSE LOADING.

24. In case any member is subject to a bending stress in addition to its stress as a member of the structure, it must be proportioned so that the algebraic sum of the stresses per square inch on the outer fibre, due,

First, to the dead load ;
Second, to the direct thrust or pull ;
Third, to the maximum bending moment produced by the heaviest loading,

shall not exceed the before mentioned permissible working stresses in tension or compression.

### SHEARING.

25. The shearing force on any member shall not exceed 7,500 pounds per square inch ; on field rivets the shearing force shall not exceed 6,000 pounds per square inch.

### BEARING.

26. The bearing on bolts, rivets, and pins, shall not exceed

12,000 pounds per square inch for iron ;
15,000 pounds per square inch for steel.

### BENDING.

27. The bending stresses on the extreme fibres of pins shall not exceed

15,000 pounds per square inch for iron ;

20,000 pounds per square inch for steel;

when the centres of bearing of the strained members are taken as points of application.

## MINIMUM SECTIONS.

### THICKNESS.

28. No iron or steel shall be used, except as fillers, of less than ⅜ inch thickness.

### WIDTH.

29. No iron in compression shall have an unsupported width of more than 40 times its thickness.

### LATERAL RODS.

30. No lateral or sway rods shall be used having a less section than one square inch.

### COUNTERS.

31. The minimum section allowed for any counter rod shall be 1½ square inches.

## DETAILS.

### TIES.

32. Cross ties shall be for

Deck bridges 8 x 10 inches x 14 feet.

Through bridges 8 x 10 inches x 10 feet.

Laid flat and dapped ½ an inch over supports and spaced 15 inches, centre to centre.

### STRESS ON TIES.

33. In no case shall the fibre stress caused by a load of 50,000 pounds on one axle carried by three ties exceed 1,000 pounds per square inch.

### GUARD.

34. There will be four pine or spruce guard rails, each 6 x 8 inches, laid flat, dapped one inch on ties, and bolted to every third tie by a ¾ inch bolt with a flat rounded headed and a square shoulder one inch long— the head to be placed upwards, and each bolt secured by two hexagonal nuts. The inner guard rails will have not less than eight inches and the outer guard rails eleven inches clearance between the timber guard rail and the metal rail.

The guard rails shall be continued for thirty feet beyond the bridge at each end—the outer ones being flared, and the inner ones brought to a point. The bolts through the outer guard rails will be connected to the stringer by means of lug washers.

### CAMBER.

35. Truss bridges are to be cambered by increasing the length of the top chord $\frac{1}{8}$ of an inch for every ten feet.

### ANCHORS.

36. Bridges must be secured from side or vertical motion.

### ROLLERS.

37. All spans of seventy feet and over must have nests of turned rollers working on planed bearings.

The weight on rollers shall not exceed $500 \sqrt{d}$ pounds per lineal inch; $d$ being the diameter of rollers in inches.

### BEARING ON MASONRY.

38. Bearing plates shall not have a greater pressure on masonry than 200 pounds per square inch.

### CONTINUOUS BED PLATES.

39. Where two spans rest on the same masonry, a continuous wrought iron or steel plate shall extend under the adjacent bearings.

### RIVET SPACING.

40. Rivets shall not be placed farther apart in the direction of the strain than six inches, nor more than sixteen times the thickness of the thinnest external plate.

Where the ties rest on the top flange, the rivets in the vertical leg of the angle shall not be more than five inches apart.

### RIVETED LATERALS.

41. Riveted laterals will be preferred to adjustable rods. It is clearly understood that the general and detail design shall be first class and satisfactory to the engineer in every respect, as these specifications are not intended to take the place of the bridge engineer.

## QUALITY OF MATERIAL.

### CAST IRON.

42. Cast iron will not be used without permission in writing from the engineer.

Except where chilled iron is specified, all castings shall be of tough gray iron, free from injurious cold shuts or blow holes, true to pattern, and of workmanlike finish ; sample piece 1″ square, cast from the same heat of metal in sand moulds, shall be capable of sustaining on a clear span of 4′ 6″ a central load of 500 pounds when tested in the rough bar.

### WROUGHT IRON.

43. All wrought iron must be tough, fibrous, uniform in quality throughout, free from flaws, blisters, and injurious cracks, and must stand the following tests :

| | TENSILE TESTS. | | | | COLD BENDING. | |
|---|---|---|---|---|---|---|
| | Elastic Limit. | Ultimate Strength. | Per cent. Elong. | Per cent. Reduct. Area. | | Diameter ; Bent Around |
| Kind of Material | | | | | | Twice Thickness of Plate. |
| Bar iron up to 4½″ square | 26,000 | 50,000 | 15 | 20 | 180 | “ |
| Bar iron over 4½″ square | “ | 48,000 | “ | “ | “ | “ |
| Channel Iron | “ | “ | “ | “ | 160 | “ |
| “ I ” Beams | “ | “ | “ | “ | “ | “ |
| Angles | “ | “ | “ | “ | 140 | “ |
| Other shapes | “ | “ | “ | “ | 120 | “ |
| Plates of 18″ and under | “ | “ | “ | “ | 160 | “ |
| Plates from 18″ to 36″ | “ | “ | 12 | 16 | 100 | “ |
| Plates from 36″ to 54″ | 25,000 | 46,000 | 10 | 10 | 90 | “ |
| Plates over 54″ | “ | “ | 8 | 8 | “ | “ |

### RIVET IRON.

44. Rivet iron shall be subject to the same requirements as tension iron of the same dimensions, and shall be further capable, without cracking or serious abrasion, of being heated to a good forging heat, made up into rivets, allowed to cool, reheated and driven as in riveting; again cooled, nicked, and cut out, when it must show a good, tough, fibrous structure, without any crystalline appearance.

### RIVET STEEL.

45. Rivet steel shall have an

Elastic limit of not less than 30,000 pounds per square inch.

Ultimate strength of not less than 52,000 pounds per square inch.

Ultimate strength of not more than 60,000 pounds per square inch.

And a minimum stretch of twenty-five per cent. in eight inches.

It shall bend double on itself without showing fracture, and after being subjected to the same practical test as iron rivets shall show a good silky fracture, with no crystalline appearance.

### STEEL.

46. Steel when tested in the specimen shall have an elastic limit of not less than 35,000 pounds per square inch.

An ultimate strength of not less than 56,000 pounds per square inch.

An ultimate strength of not more than 68,000 pounds per square inch.

A minimum stretch of twenty-two per cent. } after breaking in a length
and a reduction of area of forty per cent. } of eight inches.

It shall bend double without fracture.

### ROUGH EDGES.

47. All rolled material, iron or steel, with rough edges will be rejected.

### TEST SPECIMENS.

48. Test specimens of either iron or steel shall not be annealed, heated, hammered, forged, or otherwise treated.

### SELECTION OF TEST PIECE.

49. The inspectors shall in all cases stamp the piece of iron or steel which is to be cut off for a test piece.

### INSPECTION.

50. All facilities for inspection, testing, and weighing shall be furnished by the contractor, free of charge; and each finished member shall be weighed separately.

### ACCEPTANCE BY INSPECTOR.

51. The acceptance of any material or finished member by the inspectors shall not prevent subsequent rejection of the same if found defective after delivery or erection; and the contractor shall replace the rejected material or member without extra compensation.

### FULL-SIZED TEST STEEL.

52. Full-sized members tested to breaking must break in the body, and have an

Elastic limit of at least 33,000 pounds per square inch.
Ultimate strength of at least 56,000 pounds per square inch.
And a minimum stretch of ten per cent.

If these conditions are fulfilled, the contractor shall be remunerated for the broken members at the contract price per pound, less their scrap value.

### ANNEALING.

53. All steel which has been worked hot shall be properly annealed.

### PHOSPHORUS.

54. No steel will be accepted which has more than $\frac{8}{100}$ of one per cent. of phosphorus.

### VARIATION IN WEIGHT OR AREA.

55. No material will be accepted which varies more than 2½ per cent. in weight, or cross section from that specified.

### BLOW NUMBER.

56. Each ingot shall be plainly marked with the blow or charge number, and shall afterwards have this number stamped near the middle of each piece of finished material rolled from it.

### DRIFTING TESTS IN STEEL.

57. Drifting tests shall be made in each varying size of steel plates and angles by punching a ¾″ hole 1½″ from the edge, and shall be proven capable of having these holes expanded by means of a sledge on a drift-pin until the holes become 1½″ in diameter, without fracturing the steel.

## WORKMANSHIP.

58. All workmanship must be first-class, and satisfactory to the engineer in every respect.

### ABUTTING SURFACES.

59. All abutting surfaces must be planed or turned to insure even bearings, taking light cuts so as not to injure the end fibres, and must not be protected by white lead and tallow.

### RIVET HOLES.

60. Rivet holes must be carefully spaced and punched, and must be, in all cases, reamed to fit where they do not come truly and accurately opposite without the aid of drift-pins.

### FLOOR BEAMS CONNECTIONS.

61. All holes for floor beams, and stringer and floor beam and post connections, must be accurately drilled to an iron templet.

### RIVET HOLES IN STEEL.

62. Rivet holes in steel over ⅝″ thick shall be drilled or punched $\frac{3}{16}$″ smaller and reamed.

### PAINTING.

63. All iron or steel must receive one coat of good linseed oil as soon as rolled ; one coat of approved paint (red lead and linseed oil) before leaving the shops ; and two coats of the same after erection.

All inaccessible surfaces are to be painted before assembling. All iron or steel to be scraped clean from dirt or scale before painting.

No painting shall be done in wet or freezing weather.

### ERECTION.

64. The contractor shall furnish all the falsework and arrange the same so as not to obstruct any thoroughfare by land or water; shall furnish and erect the entire superstructure ready for the rails ; shall remove, without injuring it, and carefully load on cars, the old structure, if any ; and shall assume all risk of accidents to men or material, until the acceptance of the completed structure by the engineer.

### FINAL TEST.

65. If required by the engineer, the bridge shall be tested before the acceptance by loading it up to the requirements of the specifications for any length of time (up to 24 hours) he may desire ; the bridge must then return to its original shape, without permanent set.

## HIGHWAY BRIDGES.

### DEAD LOAD,

66. The dead load will be the weight of the structure ; the timber being assumed to weigh four pounds per foot board measure.

### LIVE LOAD.

67. The contract will state which class is to be used.

Class A will have a live load of one hundred pounds per square foot of floor.

Class B will have a live load of eighty pounds per square foot of floor.

Class C will have a live load of sixty pounds per square foot of floor

### WIND STRESSES.

68. Same as for railroad bridges.

## UNIT STRAINS.

### THICKNESS.

69. The minimum thickness will be $\frac{5}{16}$ of an inch.

### LATERAL RODS.

70. The minimum section for lateral rods will be ¾ square inches.

### FIBRE STRESS ON TIMBER.

71. The maximum fibre stress on timber will be 1,000 pounds per square inch.

## QUALITY OF MATERIAL, ETC.

72. The quality of material, inspection, painting, workmanship, erection, etc., will be generally the same as for railroad bridges.

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## **Comments.**

The following comments are numbered the same as the articles to which they refer.

7. It will be noticed that lattice girders are required for spans between 80 and 120 feet, as this is considered good practice. The writer, however, would prefer to do away with lattice girders altogether. He would use plate girders up to 90 or 100 feet, and then, if a span between a 100 and 120 feet was required, he would use a 120 feet pin connected truss. A well-designed lattice girder between these limits would probably cost more than

a good 120 feet pin, so why not use the longer and cheaper span? The New York Central R. R., under its very able bridge engineer, uses very heavy plate and lattice girders, the latter up to 200 or 300 feet span. The Coteau Bridge over the St. Lawrence has 240 feet lattice spans.

But the more the writer has to do with this kind of bridge, both in the field and shop, the more he dislikes lattice girders.

8. Double tracks on a bridge should be not less than thirteen feet apart, centre to centre; but it is not always possible to get this width without spreading the tracks, which would be objected to.

9. Most specifications call for a width in the clear of fourteen feet between trusses, but it would be much better to increase this to sixteen feet, as shown, as it would make a more rigid bridge and be safer in case of derailment, etc.; though, of course, slightly more expensive. The writer sent the Society last winter a copy of his N. & W. R. R. tables, showing the clearance required on curves.

10. The elevation suggested for the outer rail on curves is considerable, but is less than the Pennsylvania R. R. or N. & W. R. R. standards. These roads elevate the outer rail seven inches for curves of eight degrees and over.

13. It is accurate enough to consider two-thirds of the dead load as carried by the chord supporting the floor system, and, of course, saves labor, which should always be considered.

14. When engineers first began to calculate bridge stresses, a uniform load of, say, 2,000 or 3,000 pounds per lineal foot was adopted throughout the bridge. Now, while this was all right for the chords of long spans, it obviously gave results much too small for the web system, floor beams, stringers, and short spans in general, and has necessitated the renewal of many old bridges.

Theodore Cooper was the first to introduce the engine diagram, which has caused a vast improvement in the design of our bridges, inasmuch as it enables us to get the exact stress on every member of the bridge, instead of making some parts three or four times as strong as others.

But, unfortunately, this diagram business has been run into the ground, for every railroad wants its special diagram, or two or three special ones which, although giving results practically the same as the others, still, as far as the labor of calculation is concerned, are entirely different; and to aggravate the evil many roads space their wheels as so many feet, inches, and sixteenth of an inch apart. If this were necessary to ascertain the strains correctly, we would submit in silence; but it is not. In the first place, these highly complicated typical diagrams represent engines which are often never built, and, even if they are, are only some of the many kinds of engines that will pass over the bridge. This always reminds the writer of the military gentleman who paced the circumference of a circle, and then calculated the radius to six places of decimals.

Many advocate doing away with the engine diagram and using a table of uniform loads, varying for different spans, etc. The opposition to this is so great by those who assume a starting point, say, within ten per cent., and then make the rest of their calculations to one-fourth of one per cent., that it seems almost impossible to get this change adopted.

The writer believes that if the American Society of Civil Engineers were to suggest the adoption of two or three, or at the outside six, typical engine diagrams, the chief engineer of every railroad could select one to suit his railroad. Tables of shears and moments for these would then be published, and much of the drudgery of bridge calculation avoided. Calculating the stresses in a bridge is a very simple matter, though often tedious, which any machine can learn to do in a short time ; but to properly design a bridge requires years of experience in the field, shop, and office.

The simple concentration diagram given for plate girders is the same as adopted by the Norfolk & Western Railroad for all their bridges. The writer sent the Society a table giving moments and shears for spans up to eighty feet with this loading.

For truss spans the writer prefers using a uniform load, and two concentrated loads placed fifty feet apart for the sake of simplicity.

15. Some specifications adopt these wind loads without, however, allowing anything extra for spans over 200 feet ; allowing ten pounds per lineal foot for each additional twenty-five feet of span agrees very closely with C. Shaler Smith's rule of allowing thirty pounds per square foot on the train, and on twice the exposed surface of one truss, which is about right.

16. This is a simple way of allowing for curvatures, and gives safe results.

18. Mills are not required to roll iron or steel closer than two and a half per cent. in weight or shape ; why, then, use hair-splitting formulas for the rest of the work ?

19. Many specifications use tedious formulas for finding the unit stresses ; some allowing for impact as such ; others by considering the proportion of dead to live load. These are empirical, being founded on insufficient experiments. The writer sees no use of inserting such formulas in specifications. The table given has, it is true, been slightly modified from these formulas ; but it does not require every one who uses it to go through the work over again, and to carry the results out to the last pound instead of stopping at an even hundred.

Many claim that they use impact formulas for safety. Now, as a matter of fact, most of these formulas give about the same results as of old for short span, and allow much higher unit stresses for long spans, which, of course, weakens them. Now, it is quite true that in long spans the greater proportion of dead load to live load reduces greatly the shock from the train; but, on the other hand, the great length and weight of each individual member render it more liable to injury in shipping, etc. There is more play in pin holes; long members have additional stresses, due to their own weight, etc. So even in long spans we should not use unlimited unit stresses.

20. Since steel has become so popular, it is hard to get such good iron eyebars as before. The writer considers mild steel the future bridge material.

21. The straight line formulas give results which are practically as accurate as the more tedious formulas involving $l \, \overset{2}{\underset{r}{-}}{}^{2}$

28. His experience, both in the shop and field, leads the writer to strenuously oppose using iron or steel less than three-eighths of an inch thick. With less thickness the rivets are liable to crack the plates or shapes, and it is almost impossible to drive good field rivets or to cut out bad ones without injuring the work. All adjustable rods and struts affected by them should be allowed an initial stress of 10,000 pounds per square inch to allow for undue stresses in adjusting. It makes a better job to use riveted laterals instead of rods, etc.

The New York Central use a wrought iron corrugated floor on their bridges, and set the ties in ballast, which is excellent.

35. A common way of allowing for camber is to raise the centre of the span 1/1,200 of its length; but it is easier to increase the length of the top chord over the bottom chord, one-eighth of an inch for every ten feet of span.

This reminds the writer of a few more short cuts.

He had occasion to calculate the deflection of a drawbridge, when open, to find out how much the bridge should be raised at the ends to allow it to shut, and had used the following formula:

Deflection at end $= 1/E \ \Sigma (u \ l \ s)$

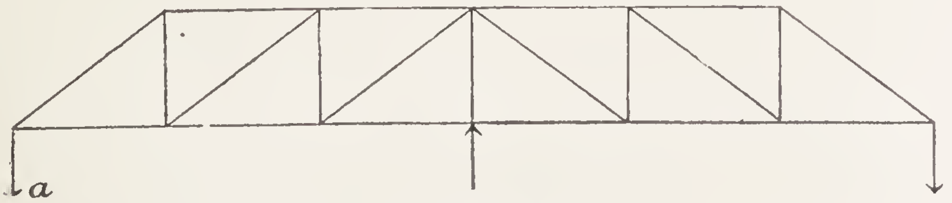


Fig. 4.

Where:

$u$ = Stress produced by 1 pound hung at "a."

$s$ = Stress per square inch in each member from dead load, span open.

$l$ = Length of member in inches.

E = Modulus of elasticity.

Now, to solve $u \times s \times l$ for each and every member in the bridge, add the results, and then divide by the modulus of elasticity, is certainly a tedious operation. It is, then, necessary to allow for pin play, etc.

He subsequently showed this formula to Mr. E. A. Schneider, of Pencoyd, who remarked he had a better formula than that. Mr. Schneider allows $\frac{1}{16}$ of an inch deflection for every ten feet of span, and said that this gave better results in practice than any other formula. In the case the writer had worked out, he had the same result as afterwards obtained by allowing $\frac{1}{16}$ of an inch for every ten feet.

Another practical short cut is for finding the radius of gyration for compression members made up of channels and cover plates, or web and cover plates.

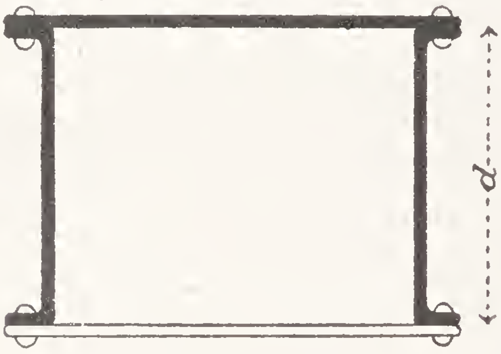


Fig. 5.

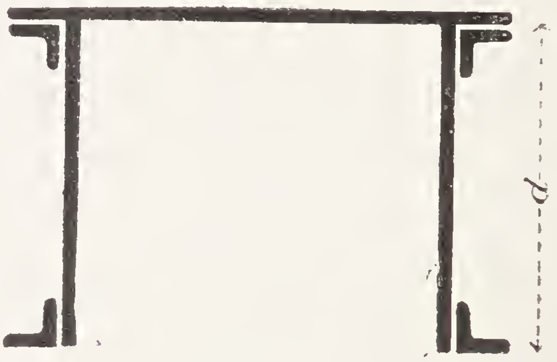


Fig. 6.

Now, we all know that it is rather a tedious job to calculate the exact radius of gyration for these sections; but if for ordinary sections, as now used, the radius of gyration is considered as $\frac{3}{8}$ of "d" (Figs. 5, 6), the result will be practically correct unless the work is for some hair-splitting crank.

37. Plate or lattice girders of over 100 feet should be set on shoes or rockers like a pin bridge; otherwise they have a tendency to rest on the first roller or edge of bed plate when the girder deflects.

A common method of calculating the expansion for an ordinary bridge is to divide the length of the span in inches by 700.

40. Rivets in stringers carrying the ties should be not more than five, or preferably four, inches apart in the web leg of the top flange angles, and should be $\frac{7}{8}$ inch in diameter. Of course, at the ends of the bridge they will be three inches apart. The writer had once to stop a prominent bridge company from using $\frac{3}{4}$ inch rivets throughout 300 and 500 feet spans, and often spacing the rivets seven or eight inches apart.

44. These results the writer obtained from examining the record of an immense number of tests; his object being to secure the highest results without making them so high that the manufacturers would have undue difficulty in living up to the specification, and therefore charging higher prices.

50. As a general rule, the inspector is handed his test piece in the testing room, and has no means of telling whether it is cut from his material or not. He might as well accept the manufacturers' word at once as go through such a farce.

53. Annealing steel, of course, reduces the hardness or brittleness, and also the tensile strength. The writer has had steel which broke at 71,000 pounds per square inch in the specimen break at 56,000 pounds per square inch in the finished eyebar after annealing, and yet he was asked why he tested the full-sized bar; had he not already accepted the material on the specimen test? The most treacherous substance in steel is phosphorus, which should never be allowed to exist in more than $\frac{8}{100}$ of one per cent.

If the pig iron contains more than the allowable amount of phosphorus, it is treated in one of two ways: either it is mixed with iron containing less phosphorus, thus reducing the proportion; or else it is treated by the acid process, which carries the phosphorus off with the slag.

63. Punching injures both iron and steel, and the conclusion drawn from many experiments is that up to 5/8 of an inch thickness the damage is not sufficient to make drilling or reaming pay. Reaming does not help as much as thought; that is, as far as remedying the injury caused by punching. The best work can be done by drilling, if the expense does not prohibit it.

64. All iron should receive a coat of linseed oil, or, better, be dipped in a hot bath of the same or some similar substance, as soon as rolled. Unfortunately, owing to the present equipment of the shops, this is a very difficult thing to get enforced, and the material is often allowed to rust in the yards before being used. It has been claimed, the writer does not know whether justly or not, that if iron once starts to rust it will go on doing so even after being painted. He has, however, taken scales 1/8 of an inch thick off iron which had been exposed to sea spray for twenty years, but apparently kept well painted. As the original thickness was only 1/4 inch, the loss was very serious. The most common paint now used in the States is metallic oxides. Why? Because it is cheap in the first cost. But red lead and linseed oil is better, and certainly cheaper in the end. Metallic paints tend to scale off.

Anchor bolts should be set in Portland cement; say, four of cement to one of sand. The old practice of using sulphur is bad. The writer has taken out old anchor bolts where the sulphur had eaten away the iron and loosened the bolts.

Bolts with wedges are not desirable; for if the wedge is driven home, it is liable to crack the stone; and if it is not so driven, it is no good. The old method of suspending floor beams by means of loop rods has been relegated to the past. It may be better to suspend them by means of an independent post firmly riveted to the ends of the floor beams. This enables strains to be concentrated better, and prevents undue bending in the main posts every time the floor beam deflects, and has none of the disadvantages of the old suspender rods.

Our bridge specifications, like our bridges, are the results of the labor of many men, so that it is almost impossible for any one man to claim the credit for our best designs of specifications. Each one selects what suits him best from his predecessors, and perhaps adds a little more ; this partly accounts for the length of most specifications.

# A TRIANGULATION SURVEY

## For a Tunnel at Niagara.

By C. H. MITCHELL, Grad. S.P.S.

MR. PRESIDENT AND GENTLEMEN :

Young engineers are generally led to look upon a triangulation survey as something belonging to the highest sphere of mathematical surveying and practice. A so-called "triangulation survey" is generally shadowed by spherical and spheroidal trigonometry, calculus, and least squares in abundance, with the accompanying shades of "single second" and micrometer transits, heliographs, long-distance signals, "sixty-mile sights," and operations in high places. We are too often liable to look upon such as the business of a few government officials, who are the soul of mystery itself, and who take no thought for the common order of things. In all this we forget that similar operations, involving similar practices on a reduced scale, are quite frequently carried on by private and public corporations for widely different objects from those which we usually attribute to such surveys.

Very few graduates (and the writer speaks from personal knowledge), when they leave college, have any idea of being for some years to come engaged in field operations on such a large scale as is required in a triangulation of even an ordinary kind. It was with such beliefs, at any rate, that three graduates of '92 (of which the writer was one) left their alma mater. It was with such beliefs still lingering that they were suddenly called on to execute a triangulation survey, on a small scale, for a tunnel at Niagara Falls.

To make a short explanation, this tunnel, as designed, was to be used as a trunk sewer to dispose of the sewage of a district of the city of Niagara Falls, N.Y., situated near the river, about a mile above the Falls. Fig. 7. The original intention was to sewer this district into the "Niagara Falls Water Power Company's" tunnel (at present under construction) by means of a vertical or inclined shaft from the surface. This scheme being abandoned for certain reasons, the city decided to have a trunk sewer built from a point near Port Day, and continuing through the city to empty into the gorge below the Falls, near the new Suspension Bridge.

It was finally decided to build a tunnel through the rock of a size of 8′ x 8′, and at a mean depth below the surface of about sixty feet. As this tunnel would be a mile long and pass under the heart of the city, a triangulation survey for it must needs be made, of a sufficiently accurate character as to enable the centre lines to be located and produced from each of the three shafts.

In a paper of this kind, it is not intended to describe in detail this proposed tunnel; the preliminary survey being the object. A few points, however, must be introduced, so as to convey a general idea of the nature of the work.

The tunnel, as proposed, was to pass under Erie Street, and parallel thereto, and continue in a straight line till it emerged at the cliff in the gorge. There are three shafts, and it is from these, together with the opening at the "portal" in the gorge, that the centre line is to be run. The running of these lines is, of course, the most delicate operation in all the surveys, and must be exceedingly accurate. There are two ways for dangerous errors to creep in: first, in the original survey, *i.e.*, in laying down the centre line of the tunnel *on the surface*, by getting the points in the several shafts in line; and, second, having the shafts sunk, and the tunnel under construction, the running of the centre line by means of plumb bobs in the shafts, etc.

Now, to particularize. This paper is to deal with the survey above ground, or the triangulation necessary to place the lines on the surface.

The first thing to be done was, naturally, a general reconnaissance of the "ground." This meant about three days "knocking about" the city and suburbs, and thinking out the ways and means, the location of survey stations, and of an economical base line. This proceeding is somewhat harder than would be supposed, as so many contingencies and obstacles are met with. I will not enter into an account of the trials and tribulations we encountered and overcame at this juncture of the work; suffice it to say that we had read a number of angles, and discarded them before we finally decided upon the arrangement of the present survey.

As for the base line, it must receive considerable attention. In this survey we had two base lines—No. 1 being situated on high level ground on the Canadian side of the river, and No. 2 on a very convenient stretch of level meadow land, in the present eastern suburbs (cut up into city lots, and selling at $30 per front foot). We made No. 2 our primary base, and used No. 1 to check on. Each line was about 1,475 feet long. No. 1 ran over very gentle undulations of grass land, having a total fall of about six

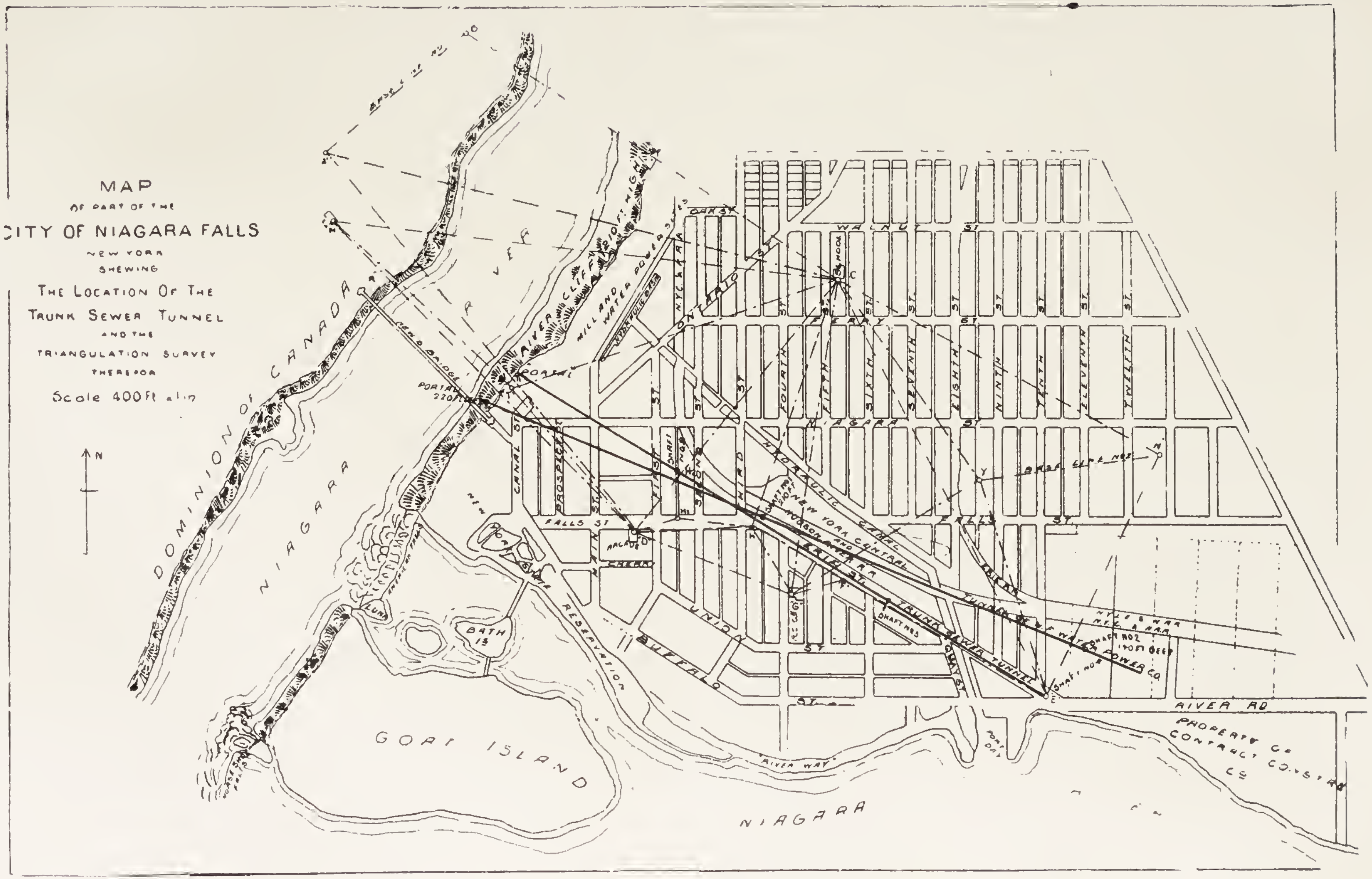

MAP
OF PART OF THE
CITY OF NIAGARA FALLS
NEW YORK
SHEWING
THE LOCATION OF THE
TRUNK SEWER TUNNEL
AND THE
TRIANGULATION SURVEY
THEREFOR
Scale 400ft a in
N
DOMINION OF CANADA
NIAGARA
RIVER
NEW BRIDGE
PORTAL
PORTAL 220 FT
RIVER CLIFF 210 FT HIGH
MILL AND WATER POWER SITES
HYDRAULIC CANAL
N.Y.C. & R.R.
OAK ST.
WALNUT ST.
ONTARIO ST.
FERRY ST.
NIAGARA ST.
CANAL ST.
PROSPECT ST.
MAIN ST.
FIRST ST.
SECOND ST.
THIRD ST.
FOURTH ST.
FIFTH ST.
SIXTH ST.
SEVENTH ST.
EIGHTH ST.
NINTH ST.
TENTH ST.
ELEVENTH ST.
TWELFTH ST.
FALLS ST.
SCHOOL
C
D
Y
N
E
ARCADE
CHERRY
SHAFT NO. 4
SHAFT NO. 3 210 FT
SHAFT NO. 5
SHAFT NO. 2 140 FT DEEP
SHAFT NO. 1
BASE LINE NO. 1
NEW YORK CENTRAL HUDSON RIVER R.R.
ERIE ST.
ERIE R.R.
TRUNK SEWER TUNNEL
TUNNEL OF N.F. WATER POWER CO.
N.Y.L.E. & W.R.R.
N.Y.C. & H.R.R.
UNION ST.
BUFFALO ST.
QUAY ST.
RIVER RD
PROPERTY OF CONTRACT CONSTRUCTION CO.
PORT DAY
RIVER WAY
STATE RESERVATION
NEW YORK
BATH IS.
LUNA
GOAT ISLAND
NIAGARA

Fig. 7.

feet. The line was run out with a transit and stakes 2″x 2″x 18″ (oak) were driven in convenient places, in depressions or summits on the line; the distances between these stakes ranging from 30 to 99 feet, so that they could be measured with a hundred-foot tape. Each stake was driven very solidly to within an inch of the surface, and had a copper tack with a well-defined head driven in it on top. The end stakes consisted of large oak stakes driven well down, and firmly supported by smaller ones; the copper tack in these having a cross cut in the head. All the stakes being driven (21 in case of base No. 1), levels were taken on each. Then commenced the actual chainage. The tape used was a hundred foot aluminium, tested and compared before using; it was graduated only in feet. In conjunction with this was used a small steel tape reading to tenths, hundreths, and thousandths. At each measurement of the line the temperature was read. A scale was attached to the tape and every reading was taken with a pull of sixteen pounds, for which we had the catenary correction to apply. In taking the first reading, *i.e.*, from stake 0 to stake 1, the distance was measured between the centre or cross in the tack in stake 0 and the south *edge* of the tack in No. 1; and the next was between the south edge of tack in No. 1 and that of No. 2, and so on, ending at the centre of the tack in the end station. In this way, ten measurements of the whole line were taken. Two men held the tape; one having the scale; while a third did the reading and took the notes.

In the office the ten readings for each short distance were first averaged; next, each average distance was corrected and reduced for temperature correction to the standard of 20° Centigrade, the correction being ·0013 feet per 1° C. per 100 feet, which is for steel—aluminium being considered the same. Then, again, each distance, where it was necessary according to the field notes, was treated to the catenary correction for a pull of sixteen pounds. All the corrections being applied, the result was (in the case of base No. 1) a set of twenty distances, comprising the whole line. These distances were in themselves the hypothenuses of the respective vertical right-angled triangles, of which the differences in elevation between the stations formed the perpendiculars. By solving these triangles, the *horizontal* distances between each two tacks were obtained, and hence the whole base line. The measurement of No. 2 base line was essentially the same as that for No. 1, except that we made an improvement by driving the stakes at distances apart of between 99 and 100 feet, so that every distance read 99 feet and a fraction, thus shortening the work.

Now, to turn our attention to the reading of the angles at the respective stations. We had, of course, four base-line stations. Two stations, very centrally situated and on elevated points, formed our principal places of operation. One of these, station C, was in the belfry of a large city school—a stone building with a heavy tower—and the other, station D, was on the top of a large brick chimney of a prominent business block. Stations H and F were so located as to be on a line parallel to the proposed tunnel. Station E was located at a convenient point near the intersection of Erie and Buffalo Streets, and as nearly in the line of H F as could be judged roughly—being unable to sight between them. These last three stations consisted of 18″ oak stakes, driven to about 6″ below the surface of the ground, and well supported by other stakes. These were then covered by a flat stone, macadam, and earth, so as not to be disturbed, but as to be easily accessible to "set up" over. Station G was the extreme top of the cross on the R. C. Church spire, and was used as a reference point only. This point was sufficiently stable to be relied on at any time, except in high wind. Station T was located on the verge of the cliff at the river, and consisted of a cross cut in the stone masonry of the foundation of a gas tank at the gas works. Station M was a point in the gable of a stone residence on the Canadian bank, and was used only as a reference point.

| | | | | |
|---|---|---|---|---|
| From Station | A | could be | seen | C and D. |
| " | B | " | " | C and A. |
| " | C | " | " | A, B, D, T, G, F, E, Y, Z, M. |
| " | D | " | " | A, M, C, G, H. |
| " | H | " | " | F, D, and G. |
| " | F | " | " | C, G, and H. |
| " | T | " | " | M and C. |
| " | E | " | " | C, G, Y, Z. |
| " | Y | " | " | C, E, G, Z. |
| " | Z | " | " | Y, C, E. |

The above table, with the accompanying "angle sheet," will serve to show what angles were read. (See table, Angle and Distance Sheet, pages 27 and 28.)

The details of the survey will now be described. The precise station consisted (as before stated) of either a copper tack (about ⅛″ head), or a chiselled cross in stone. The sight boards we used were rather an experiment, and a new idea in this kind of work. They consisted of ½″ pine boards, 6′ long and 8″ wide. They were painted red and white, in blocks of 21″ x 4″ alternately, with a dividing line down the centre. At the top was a hook from which hung a plumb line and bob, intended when plumbed to cover the centre line. The boards were placed and plumbed directly over the tacks, and guyed firmly in place by a set of three stout wires. Con-

ANGLE AND DISTANCE SHEET OF TRIANGULATION FOR TRUNK SEWER TUNNEL.

Completed September 29th, 1892.

| TRIAN. | ANGLES | OBSERVED ANGLES. | INDIRECTLY OBSERVED ANGLES. | COMPUTED ANGLES. | SUM OF ANGLES. | VARIA'N FROM 180° | CORRECT'N FOR EACH ANGLE. | CORRECTED ANGLES. | SIDES. | LENGTH OF SIDES. | LATITUDES (EAST + WEST −). | DEPARTURE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E Y Z | Z E Y | 43°04′00″ | | | | | —00″.6 | 43°03′59″.4 | Z E | 2099.314 | | |
| | E Y Z | 79°06′58″.3 | | | 180°00′01″.8 | 01″.8 | --00″.6 | 79°06′57″.7 | E Y | 1809.313 | | |
| | Y Z E | 57°49′03″.5 | | | | | —00″.6 | 57°49′02″.9 | Y Z | Base No. 2.<br>1459.768 | | |
| C Z Y | Y C Z | 27°32′16″ | | | | | +00″.2 | 27°32′16″.2 | Y C | 1999.537 | | |
| | C Z Y | 39°17′33″ | | | 179°59′55″.7 | 04″.3 | +02″.3 | 39°17′35″.3 | C Z | 2902.739 | | |
| | Z Y C | 113°10′06″.7 | | | | | +01″.8 | 113°10′08″.5 | | | | |
| C Z E | E C Z | 33°22′20″ | | | | | +01″.6 | 33°22′21″.6 | E C | 3787.090 | | |
| | C Z E | 97°06′36″.5 | | | 179°59′55″ | 05″.0 | +01″.7 | 97°06′38″.2 | | | | |
| | Z E C | 49°30′58″.5 | | | | | +01″.7 | 49°31,00″.2 | | | | |
| C Y E | E C Y | | 5°50′05″.4 | | | | 00″ | 5°50′05″.4 | | | | |
| | C Y E | | 167°42′50″ | | 179°59′56″.2 | 03″.8 | +03″.8 | 167°42′53″.8 | | | | |
| | Y E C | | 6°27′00″.8 | | | | 00″ | 6°27′00″.8 | | | | |
| C E G | G C E | 36°24′22″.5 | | | | | —01″.0 | 362°4′21″.5 | G C | 2522.152 | | |
| | C E G | 40°25′37″ | | | 180°00′01″.0 | 01″.0 | 00″.0 | 402°5′37″ | | | +2766.276 | 00.0 |
| | E G C | | 103°10′01″.5 | | | | 00″.0 | 1031°0′01″.5 | E G | 2308.334 | | |
| C Y G | G C Y | 42°14′27″.9 | | | | | --01″.0 | 42°14′26″.9 | | | | |
| | C Y E | 85°37′06″.0 | | | 179°59′59″.1 | 00″.9 | +01″.9 | 85°32′07″.9 | | | | |
| | Y G C | | 52°13′25″.2 | | | | 00″.0 | 52°13′25″.2 | Y G | 1700.672 | | |
| E G Y | Y E G | 46°52′37″.8 | | | | | 00″.0 | 46°52′37″.8 | | | | |
| | E G Y | | 50°56′36″.3 | | 179°59′58″.1 | 01″.9 | 00″.0 | 50°56′36″.3 | | | + 480. 90 | + 324.837 |
| | G Y G | 82°10′44″ | | | | | +01″.9 | 82°10′45″.9 | | | | |
| C F G | G C F | 11°46′35″.5 | | | | | 00″.0 | 11°46′35″.5 | | | | |
| | C F G | 92°57′44″ | | | 180°00′00″ | 00″.0 | 00″.0 | 92°57′44″ | C F | 2442.426 | + 897.940 | + 21.8968 |
| | F G C | | 75°15′40″.5 | | | | 00″.0 | 75°15′40″.5 | F G | 5154.472 | | |

ANGLE AND DISTANCE SHEET.—*Continued.*

| TRIAN. | ANGLES | OBSERVED ANGLES. | INDIRECTLY OBSERVED ANGLES. | COMPUTED ANGLES. | SUM OF ANGLES. | VARIA'N FROM 180° | CORRECT'N FOR EACH ANGLE. | CORRECTED ANGLES. | SIDES. | LENGTH OF SIDES. | LATITUDES (EAST + WEST −). | DEPARTURE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F G H | H F G | 35°59'40" | | | | | 00".0 | 35°59'40" | H F | 897.940 | | |
| | F G H | | 111°47'51" | | 180°00'00" | 00".0 | 00".0 | 111°47'51" | | | | |
| | G H F | 32°12'29" | | | | | 00".0 | 32°12'29" | G H | 568.373 | | |
| C G D | G C D | 30°01'48" | | | | | 00".0 | 30°01'48" | C D | 2640.131 | | |
| | C G D | | 79°51'25" | | 180°00'00" | 00".0 | 00".0 | 79°51'25" | | | | |
| | G D C | 70°06'57" | | | | | 00".0 | 70°06'57" | G D | 1342.241 | | |
| D H G | G D H | 22°46'30" | | | | | 00".0 | 22°46'30" | | | | |
| | D H G | 113°54'24" | | | 180°00'00" | 00".0 | 00".0 | 113°54'24" | D H | 1007.260 | 0.00 | + 21.8968 |
| | H G D | | 43°19'06" | | | | 00".0 | 43°19'06" | | | | |
| A C D | D A C | 37°08'43" | | | | | +01".4 | 37°08'44".4 | D A | 3993.855 | | |
| | A C D | 65°59'17" | | | 179°59'56" | 04".0 | +01".3 | 65°59'18".3 | A C | 4257.838 | − 433.494 | − 2025 72 |
| | C D A | 76°51'56" | | | | | +01".3 | 76°51'57".3 | | | | |
| C D T | T C D | 31°34'01" | | | | | 00".0 | 31°34'01" | T C | 2759.027 | | |
| | C D T | | | 78°40'16".6 | 180°00'00" | 00".0 | 00".0 | 78°40'16".6 | | | − 836. 2 | + 383.487 |
| | D T C | | | 69°45'42" 4 | | | 00".0 | 69°45'42".4 | D T | 1473 035 | | |
| C T M | M C T | 26°09'25" | | | | | 00".0 | 29°09'25" | M C | 3918.485 | | |
| | C T M | 109°08'59" | | | 180°00'00" | 00".0 | 00".0 | 109°08'59" | | | —2219. 47 | + 77. 25 |
| | T M C | | 41°41'36" | | | | 00".0 | 41°41'36" | T M | 2020.930 | | |
| C D M | M C D | 604°3'26" | | | | | 00".0 | 60°43'26" | | | | |
| | C D M | 780°2'30" | | | 180°00'00" | 00".0 | 00".0 | 78°02'30" | | | | |
| | D M C | | 41°14'04" | | | | 00".0 | 41°14'04" | D M | 3493.810 | | |
| A B C | C A B | | 54°11'33" | | | | 00".0 | 54°11'33" | | | | |
| | A B C | 106°22'32" | | | 180°00'00" | 00".0 | 00".0 | 106°22'32" | A B | Base No. 1.<br>1476.427 | | |
| | B C A | 19°25'55" | | | | | 00".0 | 19°25'55" | B C | | | |
| C E F | F C E | 24°37'46" | | | | | 00".0 | 24°37'46" | | | | |
| | C E F | | | 33°00'31".3 | 180°00'00" | 00".0 | 00".0 | 33°00'31".3 | | | | |
| | E F C | | | 122°21'42".7 | | | 00".0 | 122°21'42".7 | E F | 1868.464 | | |

derable pains were taken to get this board perfectly plumb, and keep it so. It being known to the signal man just what angles were to be read by the instrument during the day's work, he attended to the signal boards under his charge by keeping them plumb and squarely facing the line of sight. Only where a number of angles were to be read from one station were more than two signal men needed. The instrument party consisted of two men ; these, together with the accompanying signal men, constituted the survey party. Each man on the party was provided with a strong field glass, and a code of telegraphic signals (with white flags) was arranged for long-distance signalling.

The instrument used was a 7″ transit by a well-known American firm. The instrument had a power of twenty-four diameters, and was provided with all the latest improvements, including shifting centre. The graduations were on silver, and read to twenty seconds. It was supplied with a very steady extension tripod. The instrument was examined for adjustment very frequently, principally for the horizontal axis and levels.

Now, as to reading angles. Several methods were used and experimented on. (1) A repetition of ten readings—that is, (for the benefit of the junior years) reading the same angle continuously, accumulating the number of degrees. Thus an angle of, say, 60° read ten times would read 600°, or the Vernier reading would be 240°(600° – 360° = 240°). In this way, by taking the average from the final reading, the angle is determined (all things being equal) to two seconds. (2) By "four sets of five readings" —that is, four sets of five repetition readings—each set commencing at different points in the circle ; thus : (*a*) at 0°; (*b*) at 180°; (*c*) at 90°; (*d*) at 270°. (3) A repetition of *twenty* to *thirty* readings. This was the method finally adopted. It proved to be of the greatest accuracy, and involved fewer instrumental errors. By this method each angle could be read to one second, or even half a second. In reading the angles, of course the *first* reading would not be expected to give the angle any closer than ten seconds (though the Vernier really read to twenty seconds). The fifth reading should give it to two or three seconds ; while the tenth should determine it definitely to two seconds ; and, lastly, the twentieth to one second. The usual criterion for the successful reading of an angle was the relation between the results of the tenth and twentieth readings. If the angles as determined by each differed by more than 1.5 seconds, the previous results were thrown out, and the angle read again by twenty more readings.

If, during a set of observations, the instrument was known to have received a shock or jar from any cause, the whole was unclamped and the readings commenced again. If, also, it was found that the wind affected the instrument to any great extent, the operations were suspended.

### Readings Taken at Fifth Street (F),

September, 1893.

Mr.............. } Inst.
Mr..............

................ } Signals.
................
................

| Sta. Observed. | Vernier A. | Vernier B. | Remarks. | Calculation. | Mean Angle. |
|---|---|---|---|---|---|
| G | 0°-00′00″ | 0′-20″ | —<br>v v v v v | 104-47-55<br>360<br>464-47-55 | |
| C | 104-47 45 | 48′-05″ | | 10<br>5 \| 464-47-55<br>92-57-33 | 92° 57′ 33″ |
| C | 180-00-00 | 0′-30″ | +<br>v v v v v | 180-00-15<br>360<br>500-00-15 | |
| G | 75-11-50 | 12′-10″ | — | 75-12-00<br>5 \| 464-48-15<br>92-57-39 | 92° 57′ 39″ |
| G | 90-00-00 | 0′-20″ | —<br>v v v v v | 194-48-35<br>360<br>554-48-35 | |
| C | 194-48-20 | 48′-50″ | + | 90-00-10<br>5 \| 404-48-25<br>92-57-41 | 92° 57′ 41″ |
| C | 270-00-00 | 0′-20″ | + | 270-00-10<br>360<br>630-00-10 | |
| G | 165-11-20 | 11′-40″ | — | 165-11-30<br>5 \| 464-48-40<br>92-57-44 | 92° 57′ 44″<br>Final Mean = 92°57′39″ |

### Readings Taken at Fifth Street, Station F, Angle *G F C*

September, 1892.

| | | | | |
|---|---|---|---|---|
| 92° 57′ 40″ | | 1st Reading | | 92° 57′ 40″ |
| 104° 47′ 40″ | v v v v v | 5th Reading | 104-47-40<br>360<br>5 \| 464-47-40 | 92° 57′ 32″ |
| 209° 37′ 00″ | v v v v v | 10th Read. | 209-37-00 (360x2)<br>720<br>10 \| 929-37-00<br>92-57-42 | 92° 57′ 42″ |
| 59° 13′ 40″ | v v v v v<br>v v v v v | 20th Read. | 59-13-40<br>1800<br>20 \| 1859-13-40<br>92-57-41 | 92° 57′ 41″ |
| | | | Final Reading. | 92° 57′ 41″ |

The *modus operandi* of reading an angle is as follows :

(1) Set up.

(2) Set plates as accurately as possible at 0°, clamping upper plate. This is checked and corroborated by the assistant instrument man.

(3) Receive "all right" signals from stations between which angle is being read.

(4) Set telescope on the signal of that station which is to the left of the angle read, "split" it with the cross wires, and clamp the lower plate. In "setting" on the signal, the tangent screw is used in such a way that the cross wires will advance from left to right on the signal; that is, the motion of the plate is always positive in the direction of the hands of a clock. This was the case in our instrument, as in this way the tangent screw is turned against the spring. If the tangent screw were placed the opposite way, the motion would be from right to left. This is the direction in which the plates are usually graduated. If, in "setting," the wires pass beyond the signal, bring them back past the centre, and then move them up in the proper way.

(5) Unclamp the upper plate, and, moving it from left to right, set the telescope on the second signal, advancing in the proper way. Then clamp the upper plate and read the angle.

(6) Unclamp the lower plate, and move the *whole* around (left to right) until again at the first signal, on which set the wires as before, and again clamp lower plate.

(7) Unclamp upper plate and sight again on the second signal : and so on, in this way—always making every movement from left to right.

In this way the first, fifth, tenth, and twentieth readings are read and recorded in degrees, minutes, and seconds ; whilst the intermediate so-called "readings" are not recorded.

Most of our readings were taken with only one Vernier, as any index error does not enter. One man always conducted the observations on one angle, and in this way obviated the correction for personal error. The other man kept notes and checked all the Vernier readings. In this way errors in reading or sighting were quickly detected.

After considerable practice, it was found that, all being favorable, an angle of twenty repetitions could be read in from twenty to thirty minutes of time.

In the triangulation in hand, there were only five triangles in which it was possible to read with the instrument the three angles. Of the rest, with the exception of two, only two angles were read. This fact made the success of the survey much less possible, as in such cases there was no way to check on the readings. Where three angles were read, the error of closure to 180° was limited to five seconds, and was apportioned to each angle, as will be seen on the accompanying angle sheet. In a large triangulation this apportioning would have been arrived at by least squares, but in this case the errors were apportioned directly. It very often happened that such angles as were already corrected in this way would be included in *some other triangle*, and would also require a correction as regards the second triangle, in which case it was quite difficult to arrive at a result.

The calculation of the sides of the triangle of the triangulation was no small task. We found in this that system was everything, and also "the more hurry, the less speed." Having determined the exact length of the base lines on the horizontal, and having the final and accepted reading of every angle, we set to work. Four men were employed—two on each side of the table. One set started and solved a triangle on the base line; one man doing the work, and the other giving logarithms. This triangle being solved, the data used was handed across the table; and the other set of computers traced the data back to its source, and thus checked it. They then solved the given triangle any way they pleased, and compared their result with that of the first set. If the results differed by more than two or three thousandths of a foot, it generally showed that "some one had blundered," and there was forthwith a general overhauling of figures. In this overhauling one man from each set interchanged places, and the two sets then went over the work afresh. The method of giving logarithms was as follows: The computer wanting the logarithmic sine of an angle wrote the angle down on a blank slip of paper provided for the purpose, and at the upper left-hand corner wrote his initials, while in the upper right-hand corner he designated the name of the angle. This slip was handed to his assistant, who wrestled with a ponderous book of tables, found the necessary logarithm, and placed the result beneath the angle designated, together with the accompanying work. He then signed his initials in the lower left-hand corner, and passed back the slip to the computer. In this way there was no confusion by talking; the result was on paper, and an absolute check was obtained on the computers. All the logarithm slips were preserved and filed away for future reference.

By the above means, all the triangles were computed and checked, with the result as shown on the angle sheet. Wherever it was possible, the triangles were solved by the ordinary formula: $\frac{\text{Sine } A}{a} = \frac{\text{Sine } B}{b}$

I describe this method of computation so minutely because it may be valuable to some of our members as a simple and correct way, and one which we found to give entire satisfaction.

In computing we commenced at base No. 2, and proceeded toward No. 1, intending, of course, to get a result for the length of the latter which we could compare with our measured length. It may be interesting to know that the discrepancy or the error of closure in this way was .59 of an *inch*, which was considered a very satisfactory result.

This result of the calculations warranted our accepting the computed triangulation as sufficiently correct to proceed with the secondary surveys.

The latitudes and departures of all the stations were then computed, assuming a line through $E$ parallel to $FH$ as the meridian and centre line of the proposed tunnel.

Each of the shaft centres was then located by means of a secondary survey, simple in itself, but necessarily as accurate as the triangulation itself.

The surveys and works were under the direction of the city engineer, E. Z. Burns, E.M. ('87 Columbia, New York).

NIAGARA FALLS, N.Y., January 20th, 1892.

# TUNNEL AT NIAGARA

## For Development of Power.

By J. B. Goodwin, Grad. S.P.S.

Mr. President and Gentlemen,—In the proceedings of one or two of the meetings of the Engineering Society last year, several suggestions were made relative to the preparation of papers which would be of greater interest to those in the first-year courses. It was often stated, and stated undoubtedly with justice, that the wants of the first-year students were, to a great extent, overlooked ; and that if more papers were read and discussions started bearing more directly on subjects which were not so full of abstruse mathematics and complicated engineering problems, the attendance and interest of this very important part of our members would be greatly enhanced.

The want of such was greatly felt by the writer in his first year, and it may also be said, in part, of his second year ; and with this principally in view, the present paper is constructed.

In order to at once comprehend the situation, it would be well to first give a general geographical location of the work under consideration. This tunnel is driven in from the cliff which forms the east bank of the Niagara River below the "Falls," and below the new International Suspension Bridge which spans the river between the part of the present city of Niagara Falls, formerly known as the village of Niagara Falls, and Niagara Falls South, on the Canadian side. The course of the river a mile above the Falls is about at right angles to its course after its plunge into the narrow gorge below.

The main line of the tunnel is about at right angles to this latter course, which evidently will make it about parallel to the first course. The supplying of water for power in use in the mills along this bank was brought about in this way. A canal was excavated about 75 or 80 feet wide, leading from a point about three-quarters of a mile above the Falls to a basin about 350 feet from the cliff at the tunnel (Fig. 8). This basin, though excavated some years ago, was deepened in order to make of service every available inch of water entering the canal. The sill on which rests the rack at the intake was also lowered for a similar purpose. This reservoir, as it may be called, is walled up with masonry. In the "river-side" walls are placed racks and gates, admitting water to the several flumes of manufacturers which get their supply through the canal. In this particular case the water passes through the rack and gate, down a vertical shaft into the tunnel, and then into the wheel-pit, passing out from below into the river. Hence the tunnel acts as a sort of conduit, conveying water to the wheel.

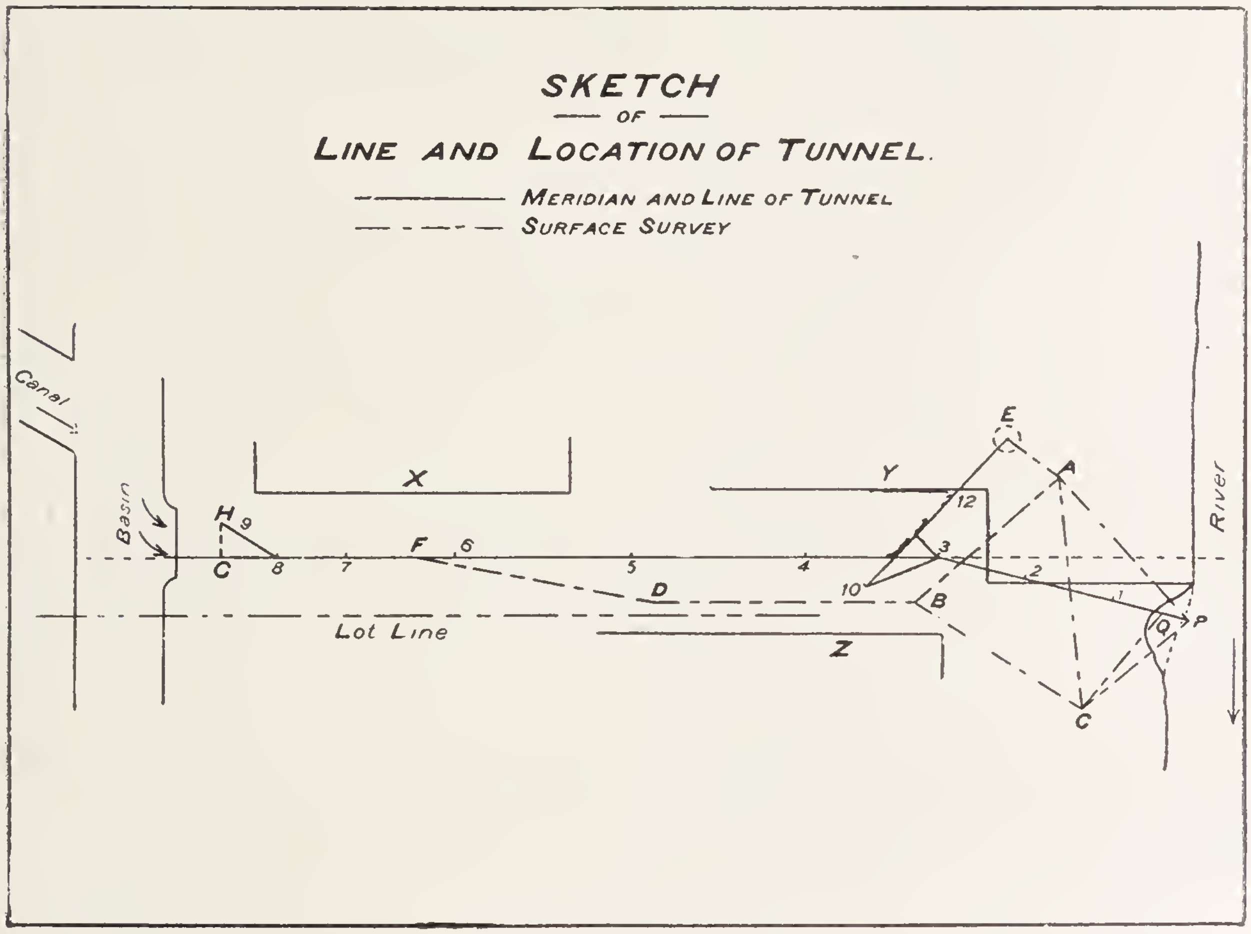


Fig. 8.

The rack at the intake is made of flat bars of iron 5/8" x 3½", placed 1½" apart, being kept apart by sleeves over long bolts or rods, which pass through at about four or five feet apart. These are all fastened to "I" beams, the ends of which are set in masonry on each side of the intake.

The whole has an inclination of three feet in twelve. This serves the purpose of collecting all sorts of grass, weeds, and sticks, of which there seems to be quite a quantity.

Before the tunnel was constructed, the water was conveyed to the wheel-pit by the ordinary flume, in which were placed two gates—one being near the intake, a short distance behind the rack, and the other in front of the rack, which is placed near the wheel-pit. Thus, with this double set of rack and gate, very little floating débris was allowed to enter the pit, endangering the wheel.

In order to increase the power and to make way for foundations for an extension of the mill, it was proposed to abandon the old flume and drive a tunnel through to a point under the intake, a few feet behind the rack at the basin. This was to connect with the intake by a vertical shaft, which is covered by a horizontal gate hinged on to a heavy oak frame around the edges of the shaft.

Now, since the wheel-pit to which access was to be made is situated under the mill, at the edge of the cliff, a small or rather short cross-tunnel was made, leading from the main artery to the wheel-pit. Near the portal and in the main tunnel is placed a gate regulating the supply to the pit. A gate is also placed at the entrance of the cross-tunnel to the wheel-pit. This will be under immediate control of workmen in the mill. The vertical gates in the old flume were raised by a simple gearing with a crank, and are let into the walls of masonry at the sides.

In the case of the horizontal gate, the means of raising and lowering are altogether different. Its construction is simple, consisting of a heavy oak frame built of required size, and laid resting on the sides of the vertical shaft alluded to, the centre of the frame in the same centre as the shaft. To this frame is hinged a strong trap-gate, which is kept shut by the head of water above it. It is opened by a chain which passes around a drum of a simple hoisting apparatus, the other end of the chain being attached to the free end of the trap.

This constitutes the description of the general features and use of the work. The method of laying out the lines and the construction proper will next deserve consideration.

As the cliff near the point at which it was desired to start the opening was about perpendicular, a ledge was made by removing a V-shaped mass out of the face of the rock, from the surface of the ground to the desired level of the floor at the portal of the tunnel.

After this was done, it was necessary to construct a sort of staging or floor over it, on which to place a windlass to handle the materials and implements used below. This consisted simply of beams let into the rock at both sides. This staging was about ten or twelve feet below the surface of the ground, but was readily accessible from it. These beams were made use of from which to suspend two wires, the line of these wires being the direction of the first part of the tunnel. Attached to the wires were weights, which swung in vessels of water, in order to prevent undue swaying. The centres of the nail-heads over which these weights were swung are the points marked P′ and Q.′ A station "C" was established near the cliff, and at a point from which P′ and Q′ could be seen. As previously mentioned, these stations were ten or twelve feet below the level of the ground on which "C" was located. It, therefore, became necessary to use a more convenient and accurate method than ordinary of arriving at the horizontal distances between " C " and P′ and " C " and Q.′ This was done by setting the transit at station " C," and sighting to the centres of the nails at P′ and Q′ in turn; then reading the angles made with the horizontal, and stretching the tape from the centre of the telescope to the points in question. Thus the measured distances form the hypothenuses of right-angled triangles, and the angles read the remaining necessary data to solve the triangles, one side of each being the horizontal distance between points.

It will be seen from the foregoing description that the points P′ and Q′ form connecting links between the surface and underground stations.

Naturally following upon this is the description of the *surface* survey. In order to aid in understanding this, it will be well to give the limits and position of the property lines. Since these lines only extended about fifteen feet from the building marked "X" in the drawing, it necessarily limited the line of tunnel to within this strip. The dotted line represents the property limit over which no part of tunnel was to extend. As the foundations had, as far as possible, to be avoided, this again limited the bounds to a strip about eleven feet wide along the building " Y." It was, however, impossible to avoid the foundations of the wing of this building, but the depth of excavation here precluded all probability of danger.

It was from the position of these buildings and lot lines that the line of tunnel was derived. Since the object was to connect with the intake at the basin, the direction was easily obtained.

Stations " F " and " G " were established on a line approximately midway between the line of building " X " and the lot line. Stations " D " and " B " were taken on a line about parallel to building " Z."

Station " A " was a point in the mill floor in the building " Y," which could be observed from " B " and " C " through doorways. The horizontal distances to this point were similarly measured as from " C " to P′ and Q′, as this floor was ten or twelve feet higher than " B " and " C." Station " E " is a point in the same floor, directly over the centre of the wheel-pit, *i.e.*, as far as the centre could be gotten at—the sides of the pit being very irregular.

These points established, the horizontal angles between them were then read, and the horizontal distances either calculated as described, or directly measured.

These points being thus fixed with reference to each other, the next thing to be considered is to connect the surface and underground points. First of all, the line of tunnel proper bisects the strip of property referred to between building "Y" and the lot line. The position of station "B" with reference to these buildings and lines being known, it is evident that it can readily be found how far station " B " is from this line of tunnel. Using a point directly opposite " B " on the line of tunnel, or *meridian* line, as it shall be called, for a reference point, or the point from which to measure *latitudes* and *departures*, a method is thus obtained to answer the requirements. Calling towards the basin positive, and the opposite way negative; and to the right positive, and to the left negative; station " B " has about 8 feet departure, and 0 feet latitude. The angle that " B D " makes with this meridian line is easily found by knowing the positions of these various lines at the ends of the buildings (these buildings and lines being divergent).

Knowing this angle and the angle that the line " B C " makes with " B D," it is easily seen that the angle that " B C " makes with the meridian can be found. Thus, knowing the distance " B C," and the inclination to the meridian, this distance, multiplied by the sine of the angle of inclination, gives the *departure; i.e.*, the number of feet to the right or left of the meridian. This same distance into the cosine of the angle gives the *latitude; i.e.*, the number of feet forward or back from the reference point. This, of course, gives the position of " C " with reference to " B." From the sketch it will be seen that the departure of " B," together with the departure of " C " from " B," gives the total departure of " C " from the meridian. The latitude of " B " (which here is 0), together with the latitude of " C " with reference to " B," will give the total latitude of " C " from the starting point of 0 latitude and 0 departure. (See table.) Thus, in brief, is the method of " Latitudes and Departures," as applied to the location of points. This description will probably be, to a great extent, superfluous; but it is repeated that it may freshen the memories of those to whom it once was familiar, and to aid those to whom it is not quite so clear.

If, now, the position of " B " is clearly understood, it can be readily seen how successive points can thus be fixed, and, after tabulating them in the order obtained, the exact location of any one point with reference to any other point can be at once determined. In this way the method of *surface* survey was carried out.

To locate and connect with these points, those in the tunnel constitutes the *underground* survey.

Slight reference was made to the hanging of plumb-lines from the stations P′ and Q′. Fine wire was used in the hanging, care being taken to suspend directly over the points to which connection was made with " C " and " B." Since the stations P′ and Q′ were only about four and a half feet apart, a slight deviation here would throw the whole line of tunnel out; hence, at these points, it required more than ordinary care.

Now, from the line given by these two plumb-lines the first thirty or forty feet of the excavation was made; but here the question might be raised as to where the point of turn-off to the main line was to be, and also how the exact distance was obtained.

However, by reference to our tabulated "Latitudes and Departures," we obtain the position of P′ and Q′, or "P" and "Q" (as they are termed on the ledge of rock about thirty-three feet directly beneath). From this, the angle that "P Q" makes with the meridian can at once be calculated; for the difference between their departures, divided by the difference between their latitudes, will give the natural tangent of the angle made with meridian. Having thus obtained the angle, it is next necessary to know how far to proceed before the turn is made. Looking into the table of "Latitudes and Departures" for the total departure of "Q," and multiplying this by the cosecant of the angle just obtained, we get the required distance from "Q" to the point of deflection. This point was called station 3, the stations underground being numbered instead of lettered, to distinguish from points in the surface survey.

After this distance was driven, a station was established exactly at the point 3. The transit was set here and sighted back to "P" and "Q," which of course should be in line; then reversed, and the calculated angle turned off. This gives the main line of tunnel, and the instrument is now in the meridian.

The method of establishing these underground stations is somewhat different from that in the ordinary surface survey. In this the stations are located in the roof, instead of floor. To establish a station, suppose, for instance, the instrument is still set at station 3, and we wish to locate station 4, farther along the tunnel; the distance is first measured off, and an approximate point located at which to drill a hole three or four inches in depth. In this hole is inserted a plug of wood, which is driven up flush with the roof. On this is established the exact point; the line being given by the instrument, and the distance by the measurement. At this point a nail with an eye on the head is driven so that the centre of the eyehole is on line, and also at the required distance.

In order to "set up" under a station, the plumb bob of the instrument is suspended from this nail, and the instrument is shifted till the point of the plumb bob is directly over the intersection of the axes of the instrument, which point is exactly under a small drilled hole on the top of telescope, when the telescope is truly horizontal.

## LATITUDES AND DEPARTURES—UNDERGROUND.

| | | | | | | LATITUDE. | | DEPARTURE. | | TOTAL LATITUDE. | | TOTAL DEPARTURE. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COURSE. | | ANGLE WITH MERIDIAN. | | | DISTANCE. | F + | B — | R + | L — | F + | B — | R + | L — |
| Q | 3 | 13° | 25′ | 34″ | Calculated | 33.85 | | 8.08 | | | 7.96 | 0 | 0 (Refer to Q′) |
| 3 | 4 | 0 | 0 | 0 | 35.41 | 35.41 | | 0 | 0 | 27.45 | | 0 | 0 |
| 4 | 5 | 0 | 0 | 0 | 67.83 | 67.83 | | 0 | 0 | 95.28 | | 0 | 0 |
| 5 | 6 | 0 | 0 | 0 | 59.93 | 59.93 | | 0 | 0 | 155.21 | | 0 | 0 |
| 6 | 7 | 0 | 0 | 0 | 77.50 | 77.50 | | 0 | 0 | 232.71 | | 0 | 0 |
| 7 | 8 | 0 | 0 | 0 | 25.00 | 25.00 | | 0 | 0 | 257.71 | | 0 | 0 |
| 8 | 9 | 22° | 46′ | 25″ | (Cal.) 15.76 | 14.53 | | 6.10 | | 272.24 | | 6.10 | |
| 3 | 11 | 30° | 58′ | 00″ | 5.83 | 5.00 | | 3.00 | | | 2.96 | 3.00 | |
| 11 | E | 44° | 09′ | 21″ | 24.09 | | 17.22 | 16.72 | | | 20.18 | 19.72 | (See surface points.) |
| 11 | 10 | 44° | 09′ | 21″ | 6.00 | 4.30 | | | 4.18 | 1.345 | 1.18 | | |

NOTE.—Stations 10, 11, and also 12, are on line of cross-tunnel.

## LATITUDES AND DEPARTURES—SURFACE.

| | | | LATITUDE. | | DEPARTURE. | | TOTAL LATITUDE. | | TOTAL DEPARTURE. | |
|---|---|---|---|---|---|---|---|---|---|---|
| COURSE. | ANGLE WITH MERIDIAN. | DISTANCE. | Forw'd + | Back — | Right + | Left — | F + | B — | R + | L — |
| o B | 90° 00′ 00″ | 8.62 | 0 | 0 | | 8.62 | 0 | 0 | | 8.62 |
| B C | 23° 55′ 00″ | 33.71 | | 30.82 | | 13.67 | | 30.82 | | 22.29 |
| C Q′ | 52° 16′ 40″ | 17.965 | | 10.99 | 14.21 | | | 41.81 | | 8.08 |
| Q′ P′ | 13° 25′ 34″ | 4.60 | | 4.47 | | 1.07 | | 46.28 | | 9.15 |
| P′ A | 49° 04′ 02″ | 27.89 | 18.27 | | 21.07 | | | 28.01 | 11.92 | |
| A E | 44° 54′ 12″ | 11.05 | 7.83 | | 7.80 | | | 20.18 | 19.72 | |
| C A | 85° 16′ 40″ | 34.37 | 2.82 | | 34.27 | | | 28.00 | 11.96 | |
| B D | 0° 28′ 00″ | 96.83 | 96.82 | | | 0.788 | 96.82 | | | 9.41 |
| D F | 5° 02′ 40″ | 110.8 | 110.37 | | 9.74 | | 207.19 | | 0.33 | |
| F G | 0° 15′ 20″ | 66.65 | 66.65 | | | .297 | 273.84 | | 0.033 | |
| G H | 75° 51′ 24″ | 6.25 | | 1.5 | 6.06 | | 272.34 | | 6.10 | |

Columns of "Total Latitude and Departure" give the location of the points to which reference is made.
NOTE.—Station "H" was not established except by calculation.

A line is produced similarly to the surface survey methods, excepting, of course, that the instrument is sighted on suspended cords or wires, which are illuminated by lights held behind them.

In giving the point of "turn-off," supposing one is required, the angle is calculated and turned off; but as this point must of necessity be near the "heading," no station can be given ahead of the instrument. The telescope is therefore reversed and a back station put in. In using these, the workmen hang lights to the nails, and work to the line thus given.

The distance along the main line was about 270 feet, and then was turned off another angle, as above described, to a point directly under the centre of the shaft, which was about 16 feet back from the basin. This shaft was driven upward, as it was impracticable to sink it, as the water could not be well kept out with the pumps employed; the floor of the intake being ten or twelve feet below water level in the basin. When they reached the point where at the drill holes water came through in small quantities, the blasts were inserted and fired; and this, with a little help from above, soon made a sufficiently large opening to drain off the water.

The work of laying the frame over the shafts could now be proceeded with. As previously mentioned, this timbering was made of oak, which was well jointed and bolted together, and set on a good rock-bed and well grouted around. The trap-gate was then hinged and the chain connected, and water allowed to enter the intake. Work could now be carried on in the tunnel in driving the cross-tunnel to the wheel-pit. The old flume could also be used while this was being done

The direction and distance of the centre of the wheel-pit "E" was arrived at as before, and lines given to work from. As this distance was short, a few blasts soon brought the "heading" within a few feet of the side of the pit. Holes were put in to within one or two feet of the pit, and left to blast till the other necessary work of placing a gate in the tunnel below this cross-tunnel was done, to regulate the supply and head, as referred to previously. A staging had also to be erected in the pit to keep rocks from falling to the wheel when the blast was fired.

The ordinary rock-drill was used. It can be used with either steam or compressed air. In this case compressed air was the working fluid, and was conducted from the air compressors through pipes. The use of air is more economical, being less liable to serious effects due to change of temperature and distance conducted. It also serves as a good ventilator, as the exhausted air is forced through the tunnel by that following. The drills were "jacked" into position, and held there with the ends of the column against the floor and roof.

Holes were sunk about six feet deep, which when blasted constituted a "heading taken out" of a depth of about five feet.

It required about twenty-four hours per heading, which in this case was about twelve cubic yards, as the tunnel was 7′ x 9′ in cross section.

The charges were fired by electricity from a battery on the surface.

The blasted material was removed by wheelbarrows and dumped over the cliff into the river.

The work was started the second week in May, and drilling was finished about the middle of October.

The kind of rock met with was limestone ; in thickness varying from six inches to two feet.

Buildings "X" and "Y" are under one management, Pettibone Cataract Paper Co., for whom the tunnel was constructed.

NIAGARA FALLS, N.Y., November 30th, 1892.

# SEWAGE FILTRATION.

By E. F. Ball, Grad. S.P.S., A.M. Can. Soc. C.E.

Mr. President and Gentlemen,—Before investigating any method of sewage purification, let us consider briefly the constituents of raw sewage and the chemical changes that are necessary to deprive it of offensive or injurious properties.

Sewage contains about 998 parts per 1,000 of water, one part of mineral matter, and one part of organic matter; and from 200,000 to 2,000,000 bacteria per cubic centimetre.

If all the mineral and organic matter and bacteria could be removed, the effluent would be pure water; but, of course, such a result would be impracticable on a large scale, and, indeed, it is uncalled for.

The mineral matter in sewage is generally unobjectionable, so there remains only the one part per 1,000 of organic matter, together with the disease-producing or "pathogenic" bacteria which require to be removed or rendered harmless.

If the bacteria alone be removed, leaving the organic matter unchanged, other micro-organisms will, before long, accumulate, and, feeding on the organic matter, set up a process of putrefaction. If the organic matter alone be removed, leaving the bacteria, they having no food will not multiply; but their spores may lie dormant, and if introduced into the human system may cause disease.

It thus becomes apparent that both the bacteria and organic matter must be removed, or so changed as to be harmless, before sewage can be considered purified.

The process of intermittent filtration does not *remove* all of the organic matter from sewage, but converts it into inorganic compounds, and it is to this important action that your attention is especially directed. It has long been known that if a limited quantity of organic matter be placed in water certain chemical changes occur, and the complex organic structure is broken down into simpler inorganic forms. This change is frequently spoken of as *oxidation*, and attributed solely to the free oxygen dissolved in the water. That this is not correct will be shown later on.

The chemical changes which occur in the breaking down of organic matter are, roughly, as follows:

(1) The oxidation of ammonia to nitrous acid.

(2) The combination of the nitrous acid thus formed with bases forming nitrites.

(3) The further oxidation of nitrites to nitrates.

Thus, *when all the bacteria have been removed or killed, and all the organic nitrogen converted into nitrates, the sewage may be considered entirely purified.*

The process of nitrification is due to micro-organisms or bacteria, and, of course, requires the presence of oxygen.

From numerous experiments, it appears that the nitrifying organism is present in all natural waters containing the ordinary amount of free or albuminoid ammonia, and in soils. It has further been observed that when the nitrifying process is in progress, the numbers of bacteria are enormously decreased.

Having thus discovered :

(1) That organic matter may be broken down into inorganic compounds by the action of micro-organisms in the presence of oxygen ;

(2) That bacterial life is almost entirely destroyed during this process ;

(3) That the organisms giving rise to nitrification are present in ordinary soils and waters ;

Let us endeavor to ascertain how these phenomena may be utilized in the purification of sewage.

If a liquid containing both dissolved and suspended matter be passed through an ordinary filter, only the suspended matter will be retained by the filter, and this is all that would be accomplished by passing sewage continuously through soil or sand. If, however, we apply a small quantity of sewage to the soil, allow it to settle, and on each succeeding day apply a similar quantity, we shall find that after a time the effluent has changed considerably in chemical composition ; the ammonias will decrease and the nitrites and nitrates increase, showing that nitrification is taking place ; while the bacteria will be almost entirely removed or destroyed.

Neither the chemical changes described, nor the removal of bacteria by filtration through sand, can be attributed to the mechanical properties of the filter, *i.e.*, by simple straining, for good results have been obtained by filtration through gravel stones as coarse as robins' eggs.

When sewage is passed intermittently through a sand filter for the first time, there is little or no chemical change, because the organisms necessary to nitrification are not present in the sand ; but, as the sewage itself contains them, they eventually find a home in the top layers of the sand, and then the process of purification commences. The filter then becomes a delicate mechanism, and the applications of sewage must be made with regularity and uniformity, and an even distribution effected over the whole surface. Should any portion of the filter be unused, the first applications of sewage to this portion will result in a poor effluent.

One of the first questions which presents itself is, what becomes of the suspended matter in the sewage? Does it clog the filter and necessitate its cleaning?

Astonishing as the statement may appear, it is found that when sewage is not applied in excess of the capacity of the filter all suspended organic matter disappears, and no crust is formed on the surface. When, however, the capacity of the filter is unduly taxed, a crust is formed which must be raked over and incorporated with the top layer of the filter.

The next question that presents itself is one of capacity. Filters five feet in depth, and composed of the following materials, may be expected to purify the quantities indicated:

(1) Coarse gravel between ¾ inch and 1¼ inch in diameter, 20,000 gallons per acre per day.

(2) Gravel between ⅛ inch and ⅜ inch diameter, under 70,000 gallons if applied hourly.

(3) Very coarse sand, from 60,000 to 100,000 gallons, with a capacity for a limited period of 175,000 gallons.

(4) Very fine sand, 25,000 to 30,000 gallons.

Fine soils six inches in depth and resting upon sandy material, although giving excellent results as to quality of effluent, have a very limited capacity.

Fine soils five feet in depth remain nearly saturated, and nitrification does not take place. The bacteria, however, are removed.

Peat, even one foot in thickness, is impervious to water, and useless.

## REMOVAL OF BACTERIA.

Although the removal of bacteria is very effective, in some cases reaching 999 per mille, it has been demonstrated that a few bacteria may occasionally pass through the filter. Whether pathogenic forms can survive the passage has not been determined.

## PURITY OF EFFLUENT.

This is to be judged by the *absence* of bacteria, the *low* percentage of free and albuminoid ammonia and nitrites, and by the *high* percentage of nitrates.

The greatest degree of purity that may be expected is the destruction of from 99 to 99.7 per cent. of the nitrogenous impurities, and the removal of from 97 to 99.5 per cent. of the bacteria.

Such effluents have been frequently used for drinking by a number of people without any noticeable effect.

### NITRIFICATION IN WINTER.

Experiments indicate that nitrification does not take place at a temperature under 39° Fah. In severe climates this might necessitate the protection of the filters from snow, and the delivery of the sewage on the filters at a temperature of 46° Fah. or over.

# THE NICKEL MINING AND SMELTING INDUSTRY OF SUDBURY.

By T. J. McFarlen, Grad. S.P.S.

The mining industry of Sudbury consists largely, as in most new mining districts, of prospecting and developing, as well as the regular work of mining and smelting.

The prudent prospector secures the latest and best map of the district he proposes to search, a geological map being a very great assistance. If he is not already familiar with the indications of the presence of deposits of nickel, he visits some of the mines already in operation; and by a close study of the spots in the adjacent country rock, and the brown gossan that often occurs where there are surface outcrops of the ore, his eye will soon be able to recognize a good indication when he meets with one. He can also learn a good deal by familiar chats with miners and trappers. The latter class are, as a rule, very observant, and will furnish a great deal of valuable information about the district they have worked. Of course, the best training in this line is to go out with an old prospector; but you cannot always pick up a good experienced prospector who is ready to run round and teach you to discover the minerals which he wants to secure for himself.

In this district the nickel ore (pyrrhotite) occurs in ridges of trappean rock, consisting largely of diorite and diabase; the ridges have a northeasterly strike.

Having selected what he considers the most promising field—which, by the way, is likely to be covered with trees—the prospector secures an outfit consisting of the map already mentioned, a pocket compass, three or four one-inch steel hand drills, a light strike hammer, a few pounds of dynamite, some fuse and detonating caps, a hatchet, a prospector's pick, a shovel, and provisions. Arrived at the field, he deposits all but his pick and shovel in a safe place, and proceeds to the search systematically by going over the field in parallel lines, a few rods apart, stopping every few rods to clear away the leaves and shallow soil, and to examine the rock if it be not sufficiently exposed. When indications of ore are found, he selects the spot where they are most promising, drills a hole, puts in a charge, and breaks as much rock with as little dynamite as possible. The first shot may satisfy him that he has a good deposit, but it may take days and even weeks of work to determine whether he is warranted in taking up a claim.

Having discovered a deposit of more or less value and taken up the claim, the next thing is to develop the deposit. This may be done by the diamond drill (the Blezard mine was tested by five or six borings with a diamond drill, to the depth of about two hundred feet), or it may be done in the usual way by sinking shafts.

After the developing has been carried on sufficiently to prove the size, character, and quality of the lode or lodes, the manager is in a position to determine the situation, character, and amount of the dead work necessary to work the mine to the required depth. I quote a few lines from the Report of the Royal Commission :

"These questions, *re* the dead work, should be settled by careful surveys made in the light of all the local facts and surrounding circumstances, such as the geological structure of the country rock, the probable amount of water to be raised, the lowest point of adit, and the most convenient point of delivery of ores to the surface.

"The preliminary exploration must have enough ore cut and under run, or otherwise exposed or determined, to give at least two years' work for reduction works of an extent sufficient for the average annual output of ore. Before erecting reduction works, the ore exposed in the mine should be so thoroughly tested as to guarantee a net profit sufficient to pay the whole cost of such work."

The further exploration of the mine is carried on side by side with the regular mining operations, the aim being to develop as much new ore as is being taken out, so as to avoid any loss from delays caused by the lode pinching out, and no new lode developed far enough to keep up the supply of ore to the works.

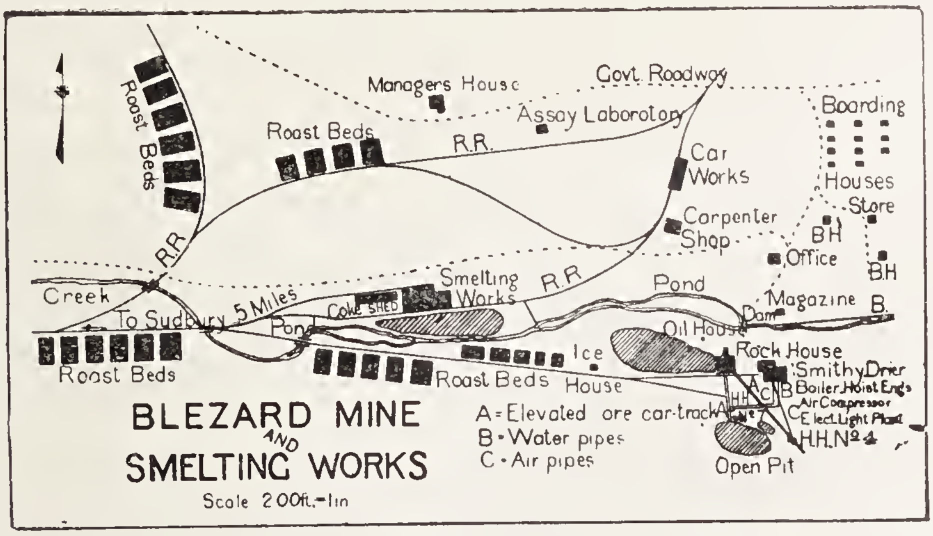


Fig. 9.

At the Blezard mine (Fig. 9) all the shafts are vertical. Four shafts have been sunk, and another one was started last summer. No. I is about

180 feet deep. Nos. II. and III. were about 50 feet, at which depth they touched the bottom of the lode, and were not continued. No. IV. is 90 feet deep. Nos. I. and IV. are 7 feet by 10 feet.

Seven power drills, driven by compressed air, are constantly at work: four drills are run in the third level of shaft No. I.; two in the first level of No. IV.; and one at the surface. The blasting material chiefly employed is black powder containing about 30 per cent. of dynamite, and called dualin. The gas from this powder is very apt to give a severe headache, as the writer found to his sorrow. The principal point in blasting, with the aim of getting the most work from the least powder, is to place the shot so that it will overcome the resistance of the rock in its weakest point; that is, its tensile resistance.

In stoping, a compromise between underhand and overhead stoping is followed. The ore in the Blezard mine occurs in large pockets, varying in depth from 30 to more than a 100 feet. The shaft is sunk to the bottom of the lode, and an inclined drift run through the lode to within reach of the highest part of the lode. Where the lode is very deep and limited in horizontal proportions, this inclined drift is forced in the form of a winding gallery. After the top of the lode has been reached, the stoping is carried on by enlarging the drift, keeping the working face as steep as possible, so that the ore cars can be brought close to the bulk of the broken ore. Large pillars are left to support the roof; these pillars are generally about 20 feet in diameter, and the distance between them varies from 20 to 50 feet, according to the soundness of the roof rock. In stoping, the drill holes are placed about 15 inches from the face of the rock, as nearly parallel to it as possible, and made of any convenient depth from 2 feet to 12 feet. The holes are placed about 14 inches apart, and loaded to within 6 or 12 inches of the top by ramming the powder down with a wooden tamping rod.

In drilling upwards the dust falls out as it is made; and in drilling downwards the hole is kept full of water, which, being constantly agitated by the drill, washes out the drill dust. The holes are called dry holes and wet holes. Before loading the latter are blown out by compressed air forced to the bottom of the hole through an inch pipe. The charges are loaded down by packing fine ore into the hole above the charge. The firing is done either by fuse and detonating caps, or by electricity. If it is an advantage to have all the shots fired simultaneously, they are connected by wire and fired by electricity. When thus fired, most of the pieces are small enough to lift into the ore car. The larger pieces are reduced by the hand sledge or mud shots. A mud shot is made by placing a quantity of powder on a flat or hollow part of the block, as near the middle of the stone as possible, attaching a fuse with cap and loading the charge down with one or two shovelfuls of fine ore, and firing it.

The ore is hoisted by a cage in the vertical shaft, the ore car is run on to the floor of the cage, and the cage is operated by a wire cable from a friction drum hoist in the engine house ; the cable passes over a pulley in the top of the head house, the head house being built directly over the shaft. A new safety cage was put into shaft No. IV. last summer. It is so constructed that, if any accident should happen to the hoist engine or the cable, as soon as the weight of the cage is taken off the cable the cage grips the guide post and comes to a stop.

The hoisting shaft is divided into two compartments, one in which the cage works is firmly timbered ; the other is furnished with a series of ladders reaching to the bottom of the shaft, and contains the air and water pipes and electric wires. A strong plank partition separates the two compartments.

A miner, with power-drill and helper, in this mine stopes, on an average, ten tons of ore in a ten-hour shift.

The average amount of ore stoped and hoisted in a double shift of ten hours each is 160 tons.

Situated, as all the nickel miners of this region are, in the most ancient formation, there is no danger or annoyance from the presence of explosive gases ; and as the country rock is very strong, and at a moderate depth quite free from weathering and frost cracks, little or no timbering is required in the drifts and stopes. The chief source of danger occurs in connection with overhead loose ground. As the blasting proceeds, there is a good deal of ground fractured which is not displaced. This fractured ground, either in the roof or walls of the stope, is constantly jarred by the drilling and blasting in the immediate vicinity ; some of it becomes gradually loosened, until it is ready to fall at the slightest jar. The presence of water veins in the ground greatly facilitates this loosening effect, as it percolates along the new fractures and acts as a lubricant between the two surfaces.

A systematic and thorough inspection should be constantly kept over all the underground workings, and all ground deemed dangerous removed. This branch of the work is called scaling, and is very important to the safety of the workmen, and often a very delicate and sometimes dangerous piece of work to perform. One or more experienced and skilled men are detailed to attend to this task.

From the cage in the head house at the top of the shaft, the ore cars are run along an elevated track to the top story of the rockhouse, and the ore is dumped close to the crusher. The crushers in general use in this section are the Blake jaw crushers. The one at the Blezard mine is the largest working in the district; it will readily crush a block of ore 10 x 14 x 18 inches. The ore crushes much more easily than the rock, but certain mixtures of ore and rock are tougher than the rock alone. The smaller sized crushers employed by the Canada Copper Cliff Co. are built to break any rock or ore you can get into them; while the large one already mentioned sometimes gives way under the strain.

The crusher is adjusted to break the ore so that the largest pieces will pass through a ring three inches in diameter. An inclined cylindrical revolving screen receives the crushed ore from the crusher; the fine ore passes through the meshes of the screen and falls into hand-cars below; while the coarser parts pass out of the lower end of the screen and fall on an inclined slide lined with sheet iron, down which they are moved by three men to the ore cars, and drawn by a locomotive to the roast beds.

The sorting of the ore at the Blezard mine is done in three places:

(1) In the mine, if a convenient place occurs, such as an old stope at a lower level, the bulk of the rock is thrown into it; failing this, the rock is filled into separate cars, hoisted, and run on an elevated track to the rock dump, or dumped into cars and drawn off to any convenient place of deposit.

(2) In the rockhouse the men feeding the crusher continue the sorting by sledging off rocky portions.

(3) At the roast beds the ore is dumped from the cars upon a wooden platform; then shovelled into wheelbarrows and run upon the roastbeds. As it is being filled into the barrows, four or five boys pick out the most rocky pieces and carry them out of the way in pails.

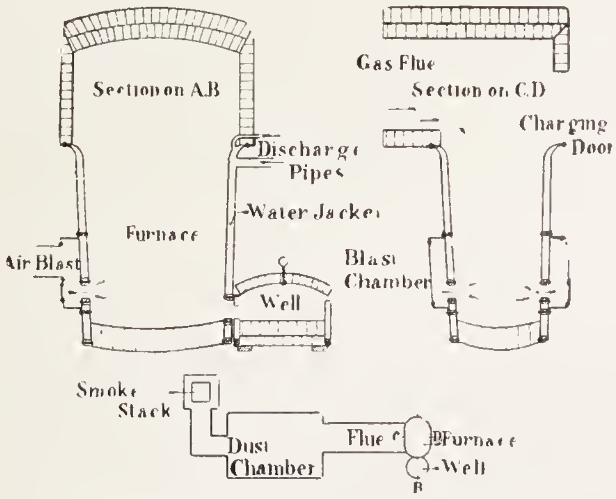
At the Murray mine the last sorting is done on a circular revolving table below the crusher by three men standing around the table; and at the Copper Cliff and Evans mines upon an inclined oscillating table by two or three men on each side of the table. At the two latter places the ore rich in chalcopyrite is separated from the ore rich in pyrrhotite, each being treated separately afterwards, and giving matters rich in copper and nickel respectively.

The ore is roasted in large heaps in the open air. The ground is levelled off and a foundation of rough wood laid down, from 20 to 24 inches deep. Temporary drafts or chimneys are provided by binding three or more sticks of wood together, and placing two to five of such bundles vertically on top of the wood foundation. The ore is now dumped on the wood foundation; first, the coarse ore, to a depth of five to seven feet, and within a foot from the edge of the foundation. The top of the bed is made flat, and the sides are left at the angle of repose, and the whole covered over with six to ten inches of fine ore. The heap is now ready for firing, which is done by pouring coal oil on the projecting wood foundation, and lighting. Before the wood is all consumed the sulphur in the ore begins to burn, and dense fumes of sulphur dioxide rise from the heap. If left to itself, the escaping gases make vents through the covering of fine ore. At these points a strong draft sets in, rapidly roasting the ore in the wake of the drafts, and then cooling down before the ore out of the influence of the drafts has been properly roasted. It is necessary, for the best results, that the whole body of ore should be simultaneously heated. For this purpose two or more men are kept watching the newly fired roast beds, and as soon as a gas vent is formed it is choked up by throwing over it a few shovelfuls of fine ore.

After the beds have been burning from six to ten days the heat subsides considerably, and the beds are left to take care of themselves. They continue to smolder for two or three months.

The object of the roasting is to drive off a large part of the sulphur and oxidize the iron, so that it will form a silicate, and slag off in the smelter.

After the roasting process has been completed, the burnt ore is loaded into cars, either by hand-barrows or by a crane, and run to the smelting house, where it is dumped into ore bins. The smelting is done in a Herreshoff water-jacketed furnace. This furnace (Fig. 10) consists of two concentric envelopes of steel boiler plate, with an empty space between the plates of one inch. The bottom of the furnace is a cast-iron plate, 1¼ inches thick, fastened on with bolts, and covered with a layer of fire-bricks set in fire-clay cement.



HERRESHOFF FURNACE

Fig. 10.

The furnace is provided with a well or receiver, into which the ore runs as it melts in the furnace. This receiver is a cast-iron water-jacketed chamber, lined throughout with fire brick set in fire-clay cement. It has three openings: one connecting it with the furnace, through which it receives the molten ore; a second one at the top of the well, through which the slag flows into metal pots mounted on wheels, in which it is run to the slag dump; and a third one close to the hearth of the well, through which the matte is drawn off. The last-named opening, called the tap-hole, is kept stopped up with a plug of finely-worked clay. About once in thirty minutes the matte is tapped off by punching a ¾-inch hole through the clay plug with a sharp iron bar and sledge, allowing the heavy sulphides of iron, copper, and nickel to flow out into a pot. When it is required to stop the discharge through the tap hole, a bud of finely-worked clay is swiftly and dexterously thrust into the hole. This bud of clay is stuck on a small circular plate attached at right angles to the end of an iron rod about twelve feet long. The bud is held firmly in the hole for about ten seconds, till it firmly adheres to its place. The well is mounted on wheels; and in case it gets clogged up or otherwise deranged, it is wheeled to one side for repairs, and replaced by another one kept in readiness.

The blast enters the furnace about a foot from the bottom, through eleven tuyeres leading from an air chamber which passes almost entirely around the furnace. The blast pressure is about five ounces.

The water for the furnace jackets, which comes from a tank elevated above the level of the furnace, enters the water-jacket near the top of the furnace, in the rear, and passes downwards around the furnace and discharges through two pipes in the front of the furnace; one of these pipes is situated near the top of the furnace; and the other, a ¾-inch pipe, passes from the highest part of the water-jacket to permit the escape of any steam that may be formed.

The discharge of the pipe is in full view of the furnace men, and, as long as water is discharging from the small one, the jacket is full of water; but if it discharge steam, the volume of water passing through the jacket must be increased until the heat from the furnace does not raise it above the boiling point.

This adjustment is made by a cock in the pipe leading from the tank to the jacket.

There are three separate water-jackets, each supplied by an independent pipe; one jacket about the furnace, a second about the well, and a third about the tap-ring.

The molten matte is very erosive, and soon eats away the iron surrounding the tap-hole. To prevent the ruin of the whole well from this cause, a large opening is left and fitted with a water-jacketed cast-iron ring. When this ring becomes eaten away too much, it is replaced by a new one of which a stock is kept on hand.

To start the furnace, a little wood is thrown in the bottom, the balance is filled with coke, and a light applied. As the coke settles down, a little ore is spread over the surface, more coke added, and the blast turned on; ore and coke are now alternately thrown in, care being taken to distribute the alternate layers evenly over the entire furnace chamber, so that each part of ore will lie over its proper proportion of coke. If this is not done, the ore in some parts will not be properly fused, and, settling down over the tuyeres, will choke the blast and cause trouble. At least one experienced charger is kept at the work, and the charge varied from time to time to suit the condition of the furnace.

So far, no mechanical contrivance has been found to work so satisfactorily as the hand charging.

When the furnace is in full blast, about 300 pounds of coke is used to the ton of ore; each charge consisting of half a ton of ore, and 150 pounds of coke, laid on in four to six layers of ore and coke alternately.

The bottom of the furnace is concave upwards, the brick hearth following the same contour; a shallow trench leads from the centre of the hearth to the furnace outlet. This form of hearth prevents the molten matte from collecting about the sides of the furnace.

To close down the furnace, the feeding of ore is stopped, and enough coke added to thoroughly fuse all ore in the furnace, and when all is in a good state of fusion a hole in the side of the furnace is opened and the contents rapidly drained off into a set of cast-iron troughs, resting on a frame at the side of the furnace. These troughs and the matte pots are covered internally with a thick wash of clay to prevent the matte adhering to them.

Sometimes the opening from the furnace to the well becomes clogged; this may be relieved by thrusting a long wrought-iron rod through the slag hole and working it to and fro in the opening referred to.

Again, if the temperature of the furnace is a little low, a crust may form on the surface of the slag in the well. This is relieved by thrusting a stick of wood into the well through the slag opening; it floats on the top, burns fiercely, and fuses the crust.

Sometimes the ore in the furnace becomes matted together in places, stopping the draft. To relieve this, a heavy iron bar is thrust into it through the charging door, and the matted part broken and pried up.

If the tuyeres become choked up, they may be relieved by opening the tuyere window and thrusting in an iron rod; but in general, when the furnace begins to block up, more coke is fed and less ore, thus raising the temperature; sometimes green ore is fed to raise the temperature, but this is sure to decrease the richness of the matte.

As the coke costs about $7.00 per ton, it is a matter of economy to run the furnace with as little coke as possible.

The furnace gases are carried along a horizontal flue from the top of the furnace to a large dust chamber. Here the gases which have a high velocity in the flue lose the greater part of their velocity, and a lot of fine ore carried from the furnace through the horizontal flue is deposited on the floor of the dust chamber. From the bottom of this chamber the gases pass through another horizontal flue, and escape through a smoke-stack, fifty feet high.

The matte from the furnace is broken up by sledges, and packed in barrels, about 1,200 pounds in each barrel; in these barrels it is shipped to market.

The daily product of the smelter at the Blezard mine is about 26,000 pounds of matte; containing about twenty-five per cent. of nickel, and twenty per cent. of copper; or, thirteen tons of matte, containing about three and a half tons of nickel, worth about $4,000, and two and a half tons of copper, worth about $400.

The amount of nickel and copper ore smelted in the Sudbury district during the year ending October 31st, 1892, was 61,924 short tons; giving 6,278 tons of common matte. The amount of Bessemerized matte, for the same year, was 1,880 tons; the amount of nickel contained in the matte was 2,082 tons; of copper, 1,936 tons; and of cobalt, 8½ tons.

The product of nickel for 1890 was about 668 tons. Thus, we see that, in two years, the product has trebled.

I do not need to speak here of the great increase in the demand for nickel in the markets of the world. Its value as an alloy with steel in the manufacture of armor plates for warships has been so well established as to call for thousands of tons yearly for this branch alone.

Of the present known nickel deposits of the world, Ontario has almost a monopoly; and we confidently expect, in the near future, a very great extension of the mining, smelting, and refining industry in this part of Ontario.

# ELECTRIC TRACTION,

## As Applied to the Street Railway.

By E. B. Merrill, B.A.

Foremost amongst the useful applications of electricity, to which a great deal of attention is being directed to-day, on account of its service to the general public, and of the great financial interests which it already represents, is that relating to traction, which, though it at present is limited to street railway service, or to use on short suburban roads, promises to extend and include the fast express and passenger traffic, if not all the railway service of the world.

In considering the subject of electric traction, we find that, though its history is short, its development has been very rapid ; so much so that, if we were to give the merest outline of its ramifications, it would require far more space than the nature of this paper would allow. We must forbear a consideration of our subject, either from an historical or a prophetic point of view ; though a glance back to the beginnings and development of the electric railway, or a dip into the probabilities or possibilities of its future, could not fail to be both interesting and instructive.

It will be our aim to consider briefly the main electrical with some of the mechanical principles of the electric street railway. The subject, then, falls naturally under three heads :

(1) The car, with special reference to the motor.
(2) The line and track, or conducting system.
(3) The station, or source of supply.

But before proceeding with these, perhaps it would be well to review the more important electrical principles upon which a great deal of what follows must depend.

First, then, as to electrical quantities.

There are three fundamental terms : Potential* ($V$) or Electromotive force ($E$), Current ($C$), and Resistance ($R$), which can be most readily understood by reference to hydraulic analogies. Potential $V$, corresponding to pressure or head, provides the force that produces the current or rate of flow against the given resistance ; which in the case of water pipes depends on their smallness of bore, or their length ; and in the case of electrical conductors increases with the decrease of cross-section, or increase of length of wire. The greater the cross-section of conductor, the greater the conductivity, or the less the resistance; the longer the conductor, the less the conductivity, or the greater the resistance.

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*Commonly spoken of also as electrical pressure, or voltage.

Since the current is a rate and the same at all cross-sections of a conductor, we may regard it as analogous to so many gallons of water per second crossing a given section of pipe.

In applying these analogies, one must guard himself against the idea that electricity is really a fluid, or that it moves along a wire when a current is said to flow. The best authorities believe that electricity is a *form of the ether*, or a part of it; that electrical phenomena are due to strains or disturbances in electricity; that when a current flows, a state of motion of the molecules of the conductor, and of a strain in the medium surrounding it, passes along from one end to the other; and that if electricity itself moves at all, it must be exceedingly slowly. Lodge accepts, provisionally, "the idea of the ether consisting of electricity in a state of entanglement similar to that of water in a jelly."

The corner stone of the science of electricity is Ohm's law,—the statement of the relation between the above three quantities: $C = \frac{V}{R}$ or $\frac{E}{R}$, or, as it is frequently used, $C = V\left(\frac{1}{R}\right)$ where $\frac{1}{R}$ is the conductivity; or, the current is equal to the quotient of difference of potential or electromotive force by resistance, or the product of difference of potential or electromotive force and conductivity. The former is used principally in dealing with resistances in series; the latter with conductors in parallel.

The electromotive force is that which produces the difference of potential, causing the flow of current between any two points under consideration. The letter $E$ is used for electromotive force, and is also commonly used for potential difference. We will use $V$, however, for this quantity, as it will assist in distinguishing the two. According to this, then, $C = \frac{E}{R}$ applies only to a closed circuit; while $C = \frac{V}{R}$ applies to any part of a circuit outside the source of the current.

A clear understanding of the following units and relations is necessary from the very outset in electrical work.

| | | | |
|---|---|---|---|
| Electromotive force, | $E$ | unit called a volt. | |
| Potential difference, | $V$ | | |
| Resistance, | $R$ | " | " ohm. |
| Conductivity, | $\frac{1}{R}$ | " | " mho. |
| Current, | $C$ | " | " ampère. |
| Quantity, | $Q = CT$ | " | " coulomb |
| Work or energy, | $EQ = ECT$ | " | " joule. |
| Power* | $= \frac{ECT}{T}$<br>$EC = C^2R$ | " | " watt. |

1,000 watts = 1 kilowatt.

746 watts = 1 horse power.

= 33,000 ft. pounds per min.

Roughly, we may take ¾ kilowatt = 1 horse power.

Now, we have to deal mostly with the pressure of 500 volts, or thereabouts, in the street railway system, as that is the pressure used in American practice, though they are trying a lower one in England of 350 volts. For every ampère, then, we have ½ kilowatt $= \frac{1}{2} \times \frac{4}{3}$ horse power, or $\frac{2}{3}$ horse power. That is, every ampère of current being used at this pressure represents, roughly, ⅔ horse power.

It is important to note that the product $VC$ or $EC$ always represents the *power* being supplied in the parts of the circuit to which these quantities refer. If a generator supply a current $C$, and generate an $EMF$ $E$, then the power expended is $EC$ watts, or $\frac{EC}{746}$ horse power. If a current $C$ passes through a resistance $R$, it does work in heating the conductor to the extent $VC$ in a second, where $V$ is the drop in potential due to the resistance. This is equal to $C_2R$, and is usually written in this way.

### THE CAR AND MOTOR.

We proceed then with the first main division of our subject—the consideration of the electric car, of which, for our purposes, the motor is the chief part, as it is the machine by which the conversion of electrical into mechanical energy is effected.

A few words, then, as to the theory and construction of the motor; and as in most cases they are reversible, we may include most of the principles of the generator. Let us take the simplest case of a bi-polar dynamo. In this the magnetic circuit consists of various modifications of the horseshoe magnet, usually of several parts—the yoke. A Fig. 11 connecting the two cylindrical cores *B*, upon which the wire *C* is wound, and at the end of these the two pole pieces *D*, between which revolve a cylindrical or ring-shaped mass of iron *E*, variously built up, also with wire wound upon it, called the armature. The armature is centred upon the shaft *F*.

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*The rate of doing work, or the rate at which energy is being transformed, or the work done, or energy transformed per unit time.

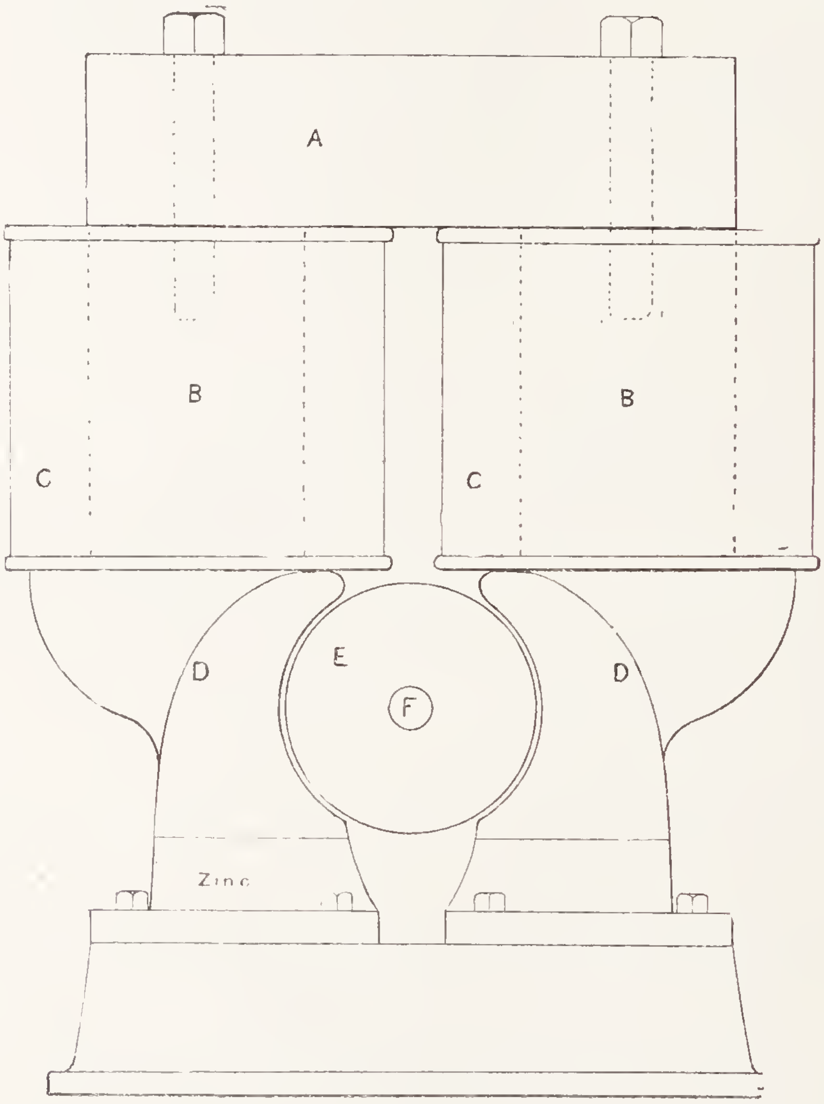

Fig. 11.

If the fields—as the horseshoe magnet or parts corresponding to it in other forms are known—are magnetized, it is now usually said that so many lines of magnetic induction, or simply so many magnetic lines, flow in the magnetic circuit; the amount of magnetism being measured by the number of lines. When the strength of the field changes, more or less lines flow in it.

With a given magnetizing force—produced by the current flowing about the field coils—certain things affect the flow of magnetic lines. Some qualities of iron allow a much greater flow than others; a large cross-section of the iron circuit allows more than a small one. Air gaps offer a great resistance to the flow of lines; it is important, therefore, to reduce them to a minimum by making the contact between the different parts of the fields as good as possible, and by making the space between the poles and armature as small as mechanical considerations will permit.

We have a similar relation between the quantities in the magnetic circuit to that which we have in the electric, viz.:

$$\text{The flow of magnetic lines} = \frac{\text{magnetizing or magneto-motive force}}{\text{magnetic resistance or reluctance.}}$$

The magneto-motive force is furnished by the electric current circulating around the fields. It is proportional to the amount of current flowing and to the number of times it encircles the fields, or, combining the two, it is proportional to the ampère-turns; the greater the current, or the greater the number of turns, the greater will be the magnetizing force, and the greater the magnetic flux.

Now, on the armature core are wound loops of wire, and for the following purpose: Consider, first, the motor. If wire is wound around a mass of iron and an electric current is sent through this wire so that it circulates in one direction about the iron, then it makes an electro-magnet of it with north and south poles. Now, like poles repel, and unlike poles attract; so that if this magnet is suspended between two fixed poles it will move until its south pole is near the fixed north pole, and its north pole near the fixed south pole; but if it be so arranged that another coil of wire then comes into play and magnetizes this movable magnet, say, in the same direction as before it was moved, the attraction of the fixed poles draws it again from this position; and if these coils are so arranged that they continually repeat this change of magnetism, then the moving magnet will continue to move. In the motor the armature is this moving mass of iron which is magnetized by the current passing around the loops of wire wound upon it, and the commutator is the mechanical means by which the current is changed from loop to loop as the armature revolves, so that its poles are continually shifted away from the fixed poles of the field, and are continually being drawn up toward them. With the armature its shaft rotates, and from a pulley and belt, or gear, etc., other machines are driven or work done.

Consider, second, the generator. If a coil of wire revolve between the poles of the fields so as to include a varying number of magnetic lines within its circuit, then as the number of lines cut increases or decreases an electromotive force is generated in the wire in one direction or the other. This causes a current to flow in the one direction, or in the other about the coil. Add to this that the completed armature is simply the mechanical arrangement of a number of coils so placed and connected as to combine the currents which flow in one direction, and those which flow in the other and send them all out in one direction by means of the commutator and brushes, and we have the outline of the theory of the generator. The current that passes around the armature magnetizes it as in the case of the motor, but the direction of motion is now reversed, and a mechanical torque is applied to draw the poles apart in generating the current. In this respect it is the reverse of the motor, for the torque applied is greater than that due to the magnetism produced by the current generated ; and, again, the one is the reverse of the other, inasmuch as in the generator the cutting of magnetic lines induces an *EMF* in the armature coils which sends out the current, and in the motor the revolution of the armature induces also an *EMF* which acts against that of the current driving it, and thereby reduces the effective *EMF* in as far as the flow of current is concerned. This opposing *EMF* is called the counter *EMF* of the motor. We shall see later how this may be determined.

The following diagrams illustrate the directions of the magnetic lines in the two cases for a gramme-ring armature.

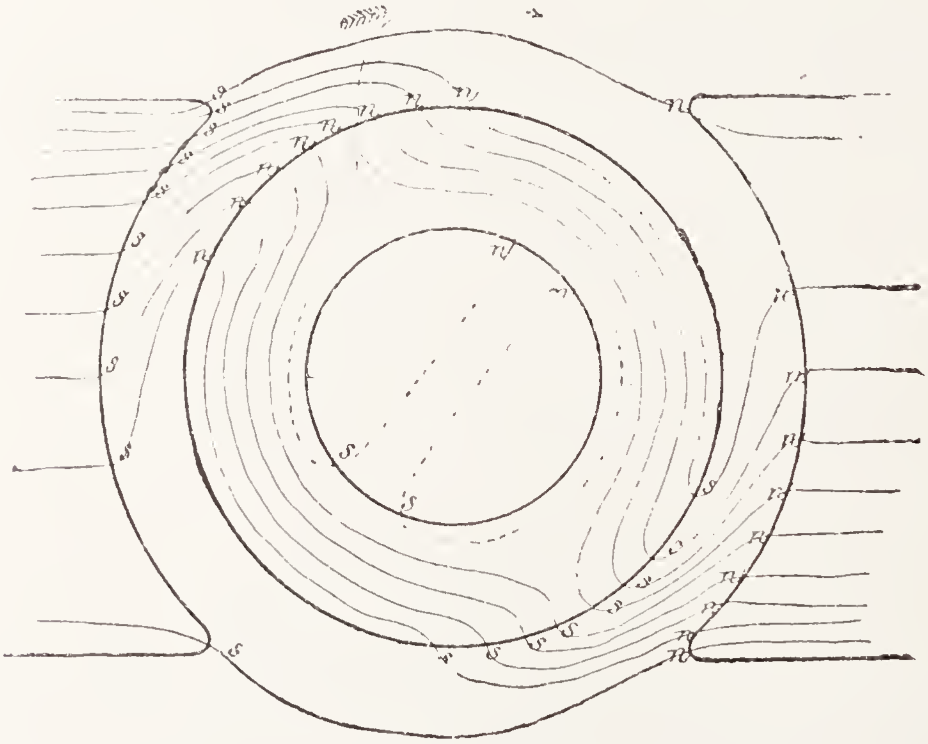

Fig. 12.—GENERATOR.

There are four principal types of motor, depending on the way the fields are magnetized, and the current supplied the armature:

1. Fields, permanent magnet or separately excited.

2. Series wound motor, when the field windings and armature are in series, and therefore the same current passes through both.

3. The shunt motor with fields and external circuit in parallel.

4. The compound wound motor, being a combination of the series and shunt.

Now, it is as transformers of energy that we have to deal with motors and generators; and providing that they are otherwise suited for their work, it is to the efficiency of transformation that we look in forming a judgment of a machine for practical purposes; for it is energy or work that is paid for, whether obtained from coal or water, or any other source.

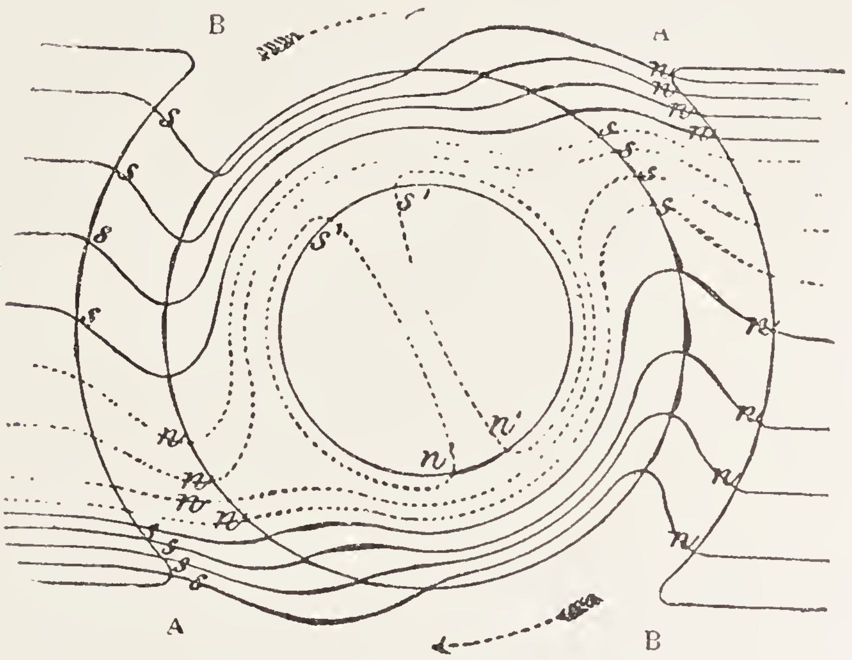

Fig. 13.—MOTOR.

The energy transformed by the dynamo is, then, the product of the *EMF* which it generates, the current which this *EMF* causes to flow, and the time $=ECT$, or the rate of transference of energy would be the power generated by the machine, and this would be the product $EC$, giving the number of watts, which may at once be reduced to horse power by dividing by 746.

The energy transformed by the motor from electrical back to mechanical again is equal to the product of the current flowing through the armature, the counter *EMF* and the time $=eCT$. The counter *EMF* $e$ is, as is the direct *EMF* in the generator, proportional to the number of magnetic lines cut per second—that is, to the strength of the field, the rate of revolution of the armature, and the number and arrangement of loops on the amature; but this last is fixed in a given machine, the others may vary. Whenever current $C$ flows through a resistance $R$, energy is expended to the extent $C^2R$; so that for a system which works at a given range of potential difference, the lost energy is kept down by reducing the resistances of generators, circuit, and motors as much as possible. The energy transformed by the generator $EC$ is equal to that re-transformed by the motor $eC$, plus that lost in heating the resistance, $C^2R$, where $R$ is the total resistance through which $C$ flows. $EC=eC+C^2R$. A small proportion of the energy is lost in the motor on account of eddy currents and hysteresis, etc., and mechanically in overcoming friction on the bearings, of the air between armature and poles, etc.

It is often convenient to represent electrical quantities and conditions graphically ; and, as we shall have some recourse to this method, let us consider the following diagrams :

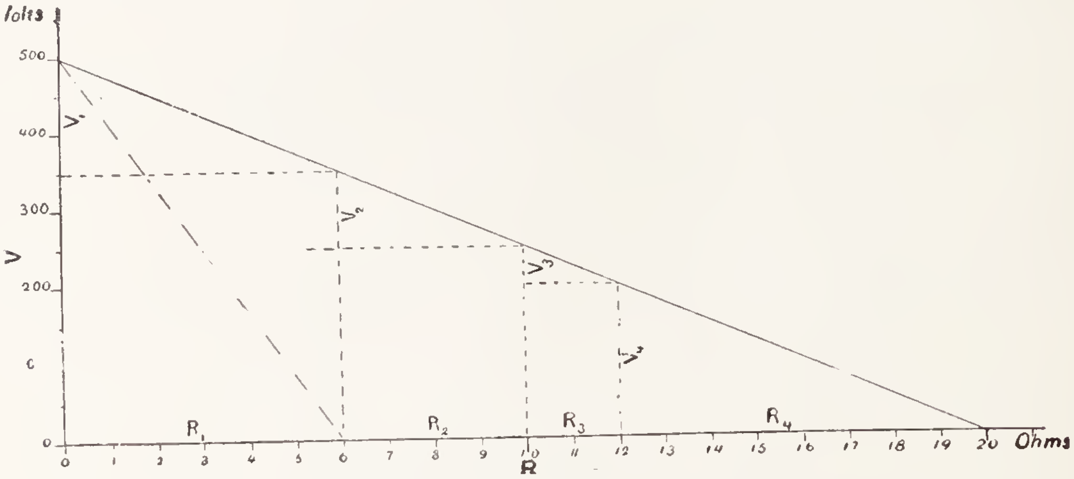

Fig. 14.

Let vertical lines represent differences of potential or electromotive forces, and horizontal lines resistances. Let $V$ be the difference of potential between the two ends of a line whose resistance is $R$ (see Fig. 14) ; then, since the drop in potential is always proportional to the resistance (when there is no addition of $EMF$), the points representing the potential at different parts of the conductor must fall in a straight line, the slant line in the diagram ; and the potential, at any point in the conductor, is measured by the ordinate to that line from the point representing the number of ohms from either end. The current flowing is $\frac{V}{R}$. If the resistance is lessened to $R_1$, and the potential difference kept the same, the line representing the potential at corresponding points in the conductor is again a straight line, but has a greater slant than in the former case. The current $\frac{V}{R_1}$ is also greater ; so that the slope of this line so drawn is a measure of the current flowing. The current or $\frac{V}{R}$ is really measured by the tangent of the angle which this line makes with the horizontal.

For a circuit of varied resistances in series, since the same current passes through all, the slant line must have the same inclination throughout. $C = \frac{V_1}{R_1} = \frac{V_2}{R_2} = \frac{V_3}{R_3} = \frac{V_4}{R_4} = \frac{V}{R}$

Where an *EMF* is being added, as in the case of a battery dynamo, or the line representing the change of potential is altered, and is no longer an indication of the current (Fig. 15), the ordinates are increased proportionately to the *EMF* added, and this increase may vary according to any curve, depending on the form of generator used, as, generally, it is not proportional to the internal resistance.

In Fig. 15, *P* represents the positive and *N* the negative pole of the battery or dynamo. *V* is the difference of potential between the poles or brushes, as measured by a volt meter.

In the street railway service, the generators at the station are so designed that they may maintain a practically constant difference of potential between their brushes. The generated *EMF*, of course, must vary with different conductivities of the external circuit in order to maintain this difference of potential at the brushes. This is also illustrated in Fig. 15.

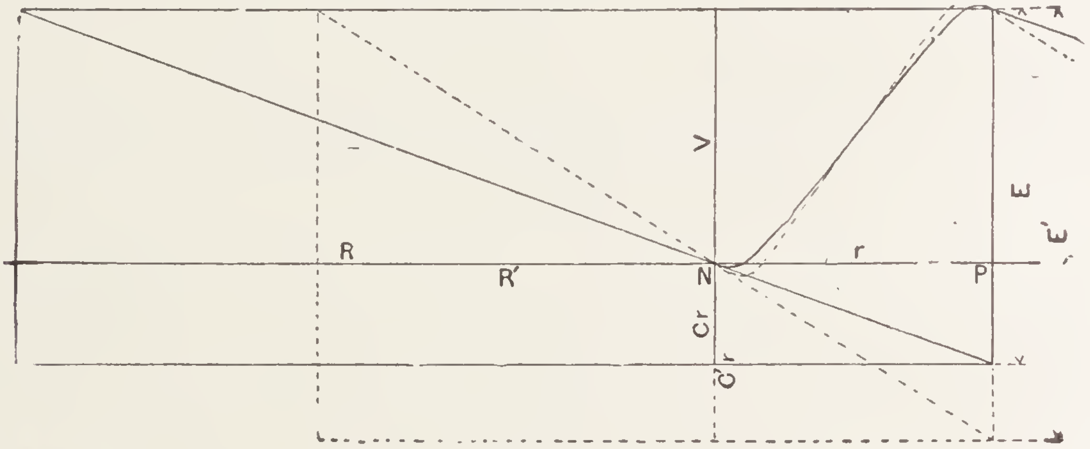

Fig 15.

$$C = \frac{E}{R+r} = \frac{V}{R} = \frac{E-V}{r}$$

$$C' = \frac{E'}{R'+r} = \frac{V}{R'} = \frac{E'-V}{r}$$

$$E = V + Cr.$$

$$E' = V + Cr.$$

The electromotive force $E$, generated by the dynamo, is seen by referring to the graphical representation to be the sum of the difference of potential between the brushes $V$ and the product of the current flowing and the internal resistance of the armature $Cr$. $E = V + Cr$. The greater the current, the greater must $E$ be to maintain $V$ constant.

Again, $C = \frac{V}{R}$; that is, the less the resistance in the external circuit, the greater will the current be. With the street railway, every time a car makes connection with the line, it makes a new path for the current; that is, supplies an increase of conductivity, or lowers the resistance of the circuit so that more current will flow. This is what is required to drive the cars.

As the motors are designed to give efficiency at the difference of potential, $V$, on the line, the resistance of the line must not be so high as to make a very great drop along it before reaching the farthest car, Best practice requires that this drop be not greater than fifty volts as an average, or a maximum of 100.

The following diagram, Fig. 16, illustrates the relations between $C$, $E$ and $R$ on a circuit with generator and motor.

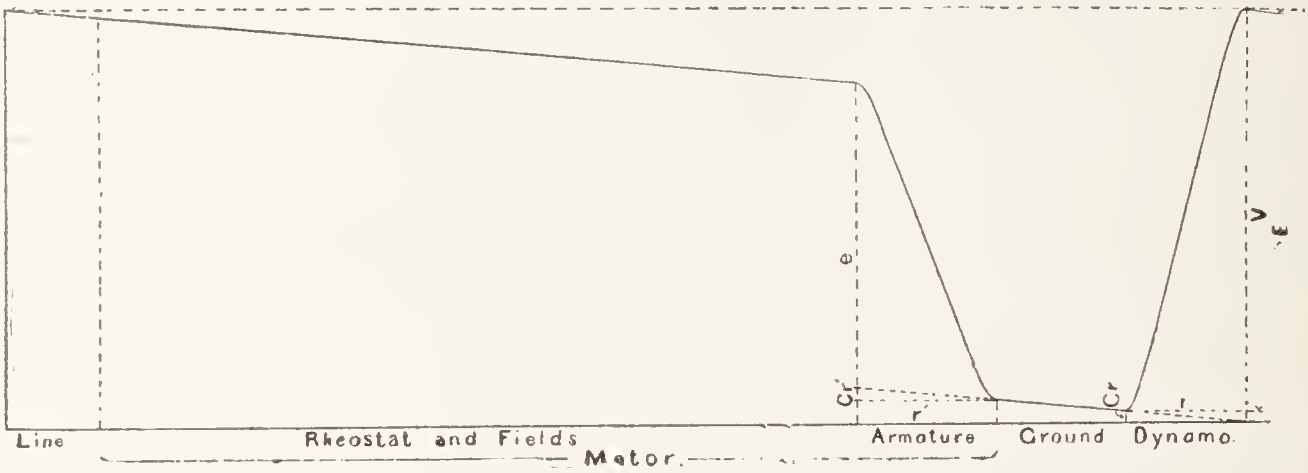

Fig. 16.

$E$ = generated $EMF$ $e$ = counter $EMF$. $E - e$ = effective $EMF$.

$C = \frac{E-e}{R}$, where $R$ is the total resistance of the circuit.

To find the counter $EMF$ which is being generated by a motor at any time, we take the difference of potential between the brushes, and subtract from this the product of the current flowing and the internal resistance of the armature. If the internal resistance is not known, or cannot be determined practically by bridge measurement, then it may be calculated by holding armature fixed and passing a known current $C_1$ through $V_1$, measuring the difference of potential between the brushes, and then $r = \frac{V_1}{C_1}$, which may be used above. $e = V' - Cr' = V' - C\frac{V_1}{C_1}$; and if the current is the same in both cases, we have $e = V' - V_1$.

The resistance of fields in series with armature of motor will have the same effect on the power of the motor as an extra resistance in line.

The efficiency of a motor is measured by the ratio of the energy which is transformed by it per second, which is used in driving the armature shaft and car wheels or other work, as the case may be, to the energy per second which is supplied by the generator. Another efficiency is the ratio of the work done by the motor to the work done in the dynamo by engine, etc., which drives it ; another is the ratio of the work done by the motor to the electrical energy supplied by the dynamo ; but in both these cases, if we are simply considering whether the motor does its work well as compared with other motors, it is evidently unfair to it to charge it with either the mechanical losses in the driving of the dynamo or of the electrical losses in dynamo and line. So that, if we want to know how to rate a motor for its work, we must consider the energy supplied to it between its two terminals, or in the street-car motor between the trolley and the ground, and consider how it makes use of it. We charge it with the energy which is wasted in heating the field and armature windings, as well as that used in driving the armatures.

Let us take $V_m$ as the difference of potential used by the motor between line and ground at the car. This will be less than the generated *EMF* by the amount lost in generator, feeding system, and connection with ground. We have then the electrical power passing through the motor as $V_m\ C$; the amount transformed is $eC$; the efficiency of the transformation will then be the ratio of the latter to the former, or $\frac{eC}{V\ \ C}$ or $\frac{e}{V_m}$; so that the greater $e$ is, the greater will be the efficiency. But, at the same time, the greater $e$ is, the less will be the current $C = \frac{V_m - e}{R}$; so that the rate of work done by the motor $eC$ decreases when $e$ becomes too large. This work is a maximum when $e = \frac{V_m}{2}$, but then the efficiency is only one-half.

These are two important points : As $e$ approaches the value $V$ the efficiency increases ; as it drops towards $\frac{V_m}{2}$ the power of the motor increases.

The following diagram illustrates this :

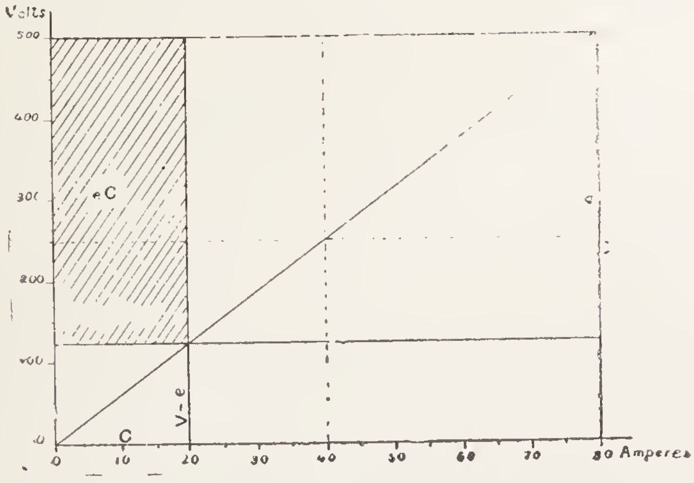

Fig. 17.

Horizontal distances represent currents, and vertical ones differences of pressure. The hatched area represents the work done by the motor, and this is a maximum when $e = \frac{V}{2}$, as is readily understood. The efficiency is $\frac{e}{V}$.

Take as possible values in the equation: power of motor $= eC = e\frac{V-e}{R}$

| | | WATTS. | H.P. | EFFICIENCY. |
|---|---|---|---|---|
| (*A*) | $eC = 240.\frac{500-240}{10} = \frac{240 \times 260}{10}$ | $= 6240$ | $= 8.32$ | 48% |
| (*B*) | $= 250.\frac{500-250}{10} = \frac{250 \times 250}{10}$ | $= 6250$ | $= 8.33$ | 50 |
| (*C*) | $= 260.\frac{500-260}{10} = \frac{260 \times 240}{10}$ | $= 6240$ | $= 8.32$ | 52 |
| (*D*) | $= 300.\frac{500-300}{10} = \frac{300 \times 200}{10}$ | $= 6000$ | $= 8.00$ | 60 |
| (*E*) | $= 400.\frac{500-400}{10} = \frac{400 \times 100}{10}$ | $= 4000$ | $= 5.33$ | 80 |
| (*F*) | $= 450.\frac{500-450}{10} = \frac{450 \times 50}{10}$ | $= 2250$ | $= 3.00$ | 90 |

A motor should be designed for a high efficiency for average running conditions; say, 90 per cent. A much greater power may be obtained from it then, when specially needed, when the efficiency is not of importance. The efficiency affects most the cost of running the motor; so that the average running conditions affect the cost, and not, particularly, special demands on it.

Let us consider how $e$ may be increased. As we have seen, it depends on the rate at which the conductors on the armature cut magnetic lines. This depends on:

(1) *Number of loops on the armature, and its diameter.* This is limited by considerations of mechanical design for strength, size, etc., as well as the space required for magnetic core, for good insulation, and for low resistance conductors to save energy in heating, and prevent burning out. The most danger arises to a motor from this cause when the car is just starting. The armature is not revolving, and therefore $e$ is zero; there will then be a rush of current, due to $V$, through the windings of the motor $C = \frac{V}{R}$ which may be great enough to produce serious effects.

(2) *The rate of revolution of the armature.* This, again, depends on the rate of travel of the car (or the average rate), or to the amount of reduction between the speed of the armature shaft and that of the axle. The question of double or single reduction or of gearless motors comes under this head.

(3) *The strength of field.* This depends on the number of ampère turns about the fields up to the point of saturation, and to the amount of cross-section of the magnetic circuit, as well as on the permeability of the iron or steel used. The latter is fixed in the design. As it is important always to have a strong field, it is usual to design the motor so that the lowest current keeps the fields nearly up to saturation.

The ampère turns may be altered by what is known as field commutation, which affects the number of turns, as well as the current, by altering the resistance of the fields. An added external resistance is also used for decreasing the current. Some systems use it entirely instead of the field commutation, but the best combine the two, using the external resistance, especially for starting, to prevent a heavy rush of current through the motor. Of course, energy is lost in these added resistances; so that they should not be used for average running conditions.

A great deal of trouble, however, has been experienced with motors with commutated fields on account of the difficulty of providing good insulation in the limited space allowed them.

Field commutation is resorted to more on account of the changes of resistance, and therefore of current flowing through the motor which it affects, than for changes in field strength. There are, as a rule, three sections in the fields, which are designed to produce progressive effects by the following combinations; these being affected by the cylindrical switches which are placed on the end platforms of the car, to be used one at a time as required. In nearly all cases in the present practice, the fields and armature are in series:

(*A*) The three coils in series.

(*B*) One cut-out, or short-circuited; the other two in series.

(*C*) Two in multiple, with other in series.

(*D*) Two in multiple, the other cut-out or short-circuited.

(*E*) All three in multiple.

The Edison controlling switch has seven positions: The first, *A*, with an external resistance in series; $2 = A$; $3 = B$; $4 = C$; 5 has two in multiple, with the third short-circuited; 6 two in multiple, with the third cut-out; and $7 = E$. There is practically no difference between 5 and 6.

Supposing, as an example, a motor designed for efficiency at a rate of ten miles per hour, and that the fields are nearly saturated with the smallest number of ampère turns employed, and that it is running with combination (4) or (*C*) at this efficiency. Then by changing through (3) (2) to (1) we decrease the current, and therefore the product $eC$, and therefore the work done, or the speed, since the field remains nearly the same. This lessening of speed reacts in lowering $e$, which allows an increase of current, tending to increase the speed until a balance is reached. The motor is then running at a lower speed with a lowered efficiency.

Or let us pass to combination (7) or *E*. $R$ is diminished, and therefore $C$ increased, and the product $eC$ increased, and the speed; since $e$ is not altered much from the change of current. But the increase of speed increases $e$, which reacts on $C$ to decrease it, tending again to decrease the speed until a balance is obtained. The speed is increased and the efficiency at the same time.

The series motor appears to have a number of advantages over the shunt:

(1) The slowness of magnetization of the fields in the shunt motor, due to self-induction, and a consequent abnormal rush of current through the armature in starting.

(2) Regulation of current and field strength effected by field commutation in the series motor.

(3) The fields used as a resistance in the series motor.

(4) Insulation of series motor more easily made on account of lower difference of potential at the brushes.

(5) Automatic field regulation up to the point of saturation in series motor.

The mechanical considerations relating to motor and car pertain to the position of the motor and the nature of its connection with the axle. On its position depend the readiness with which it can be got at for inspection or repairs; its protection from dust; whether it occupies space or not, which would interfere with the carrying capacity of the car; and its dimensions when attached to the axle, with a view to leaving a sufficient space between it and the ground.

Special precautions must be taken to keep dust out of the motor and gears by coverings of various kinds. The spur wheels are sometimes allowed to dip or run in oil in a tight case that surrounds them, which reduces the wear and noise.

The car now used commonly has two motors, which are placed beneath the flooring, one connected with each axle.

Different methods have been used for connecting the armature shaft to the axle; such as (1) spur gears; (2) sprocket chains; (3) bevelled gears; (4) connecting rod, as in locomotives; (5) worm gears; (6) ordinary belting; (7) ropes and pulleys; (8) friction plates; (9) gearless, or centering of armature on axle.

Most roads now use spur gearing with single reduction; a small cogged wheel on the armature shaft being geared into a larger one on the axle, or sometimes two sets of such wheels are used side by side; the one set staggered with respect to the other; that is, set one-half pitch farther ahead.

In most types of motor part of the weight rests directly on the axle, the rest being supported by spring connections to the truck. Where too much weight is supported directly on the axle, it causes great wear on the tracks from pounding. Spring connections obviate this difficulty to a great extent.

The other modes of connection have been tried, but must have been discarded on account of their greater complication and losses of efficiency due thereto. One especially is likely to survive, and may yet displace the single reduction spur gear which is now the favorite, and that is the gearless motor, in which the armature is centered directly on the axle. This is the ideal as regards simplicity, and has been making considerable headway. Objections to it that have stood in its way have been that the speed of revolution of the armature is reduced, and therefore that the strength of the fields must be greatly increased; or that the diameter of the armature must be considerably greater that the speed of the rim may be greater; or that the number of turns on the armature must be increased; that the electromotive force may be kept up for good efficiency. The torque on the armature is also increased by increasing its diameter. But all these changes conflict with the necessity of keeping dimensions down on account of the very limited space allowed the street car motor between floor of car and ground.

The current enters the car by way of the trolley, whence it does its work, and passes to ground through the bearings and wheels.

First, there is a wire from the trolley leading to each end of the car to the controlling switches, which are placed on the platforms. Through these switches, as they are thrown into the different positions, the current is sent through different wires to a central point in the car, where it divides and goes through the same parts of the two motors and then to the ground.

Another circuit passes from the trolley to supply lamps in the car, of which there are enough in series to make up the required potential thus:

five 100 volt lamps are usually used in the 500 volt circuit. There is another circuit when heaters are used, and an open one for lightning arrester.

The lightning arrester is an instrument which provides a gap in its circuit across which the current at 500 volts will not jump, but the high potential lightning leaps across and thence to ground in preference to the longer paths through the motors. The regular current usually follows the lightning across this gap, so that some contrivance is usually provided to break this arc automatically. Lightning arresters are indispensable for the preservation of motors during thunderstorms.

There are switches and cut-outs in each circuit. The cut-outs are provided with properly graded fuse wire, which burns out when the current increases to an extent dangerous to the circuit on which it is placed. The failure of fuse wire to go at the right time is the cause of many burn-outs in fields and armatures of motors.

The number and style of cars to be used will depend on the service required, and on the length of line or lines.

Suppose that we require a five-minute service between two points, five miles apart, at an average speed of ten miles per hour—each car will make a round trip in one hour; so that there must be a car for each five minutes between the time it starts one trip and the next one hour after, or twelve cars in all. If it were essential that this service should be maintained constant, then there would need to be several cars extra to rely upon in case of breakdown or stoppage for repairs. The demands of the case will determine whether single motor cars are to be used, or with trailers; it being less expensive, if the service will allow, to run motor cars with trailers, if motors are constructed for that purpose, than to run two motor cars carrying the same number of passengers.

## THE LINE.

Under the head of *Line* is usually comprised the whole conducting system, from the dynamo out through the feeders and trolley wires, and from the cars through the track and ground back to the dynamo again.

The principal problems connected with the line are:

(1) The determination of the arrangement and dimensions of the trolley lines and their points of connection with one another and with feeders.

(2) The arrangement and dimensions of feeders.

(3) The subdivision of the line into separately fed sections.

(4) The suspension and insulation of the trolley line, trolley wire crossings, frogs, switches, insulation crossings, guard wires, and, generally, overhead construction.

(5) The bonding, that is, the cross or end connecting of the rails, or connecting them to ground.

There are a number of different ways in practice of connecting feeders and trolley lines. The more important are:

(1) The single trolley line with feeder to nearest point.

(2) A feeder running the full length of the trolley line, and connected to it at intervals of 500 to 1,000 feet,

(3) Same as (2), but trolley line divided into sections midway between points of connection with feeder.

(4) Continuous line fed at intervals with independent feeders.

(5) Same as (4), but trolley line divided as in (3).

(6) The ends of the sections in (3) and (5) are often connected to the feeders instead of the centres. This virtually doubles the capacity of the trolley line by allowing the current to flow from both ends of a section at once to cars in between.

The settling of the general arrangement as regards subdivision of line and relation of feeders and trolley wires depends on the following data:

(1) The length of line or lines, and their position with regard to the station.

(2) The service required of the line, and therefore the average and maximum current to be supplied.

(3) The initial pressure at the station.

(4) The minimum pressure allowable in trolley wire at average or maximum load.

(5) The line should be divided into shorter sections in parts of a city where there is danger of fires occurring, so that only a small part of the line need be out of service at a time from this cause.

The position of the line, the service required, and the general nature of the road as to grades, etc., are the primary conditions to be considered in the projecting of a street railway from an engineering aspect.

From these we may obtain an idea of:

(*a*) The maximum number of cars likely to be simultaneously in use on the line.

(*b*) The number on the level and ascending and descending grades, their speed, and power used.

(*c*) The weights to be carried and horizontal effort per ton weight required; that is, the co-efficient of traction.

Having settled these questions, we readily deduce the effective power required for the whole system for the use of the cars and the distribution of the power along such lines. Then, knowing the efficiency of transformation of the motors used under the given conditions, and also the loss of energy in heating the resistances of the line, we may determine the electrical energy required to be supplied by the station to meet these demands.

The power required per car consists of three parts :

(1) That lost in the transformation, electrical and mechanical.

(2) That used in lifting the car against gravity on grades.

(3) That used to move the car along the rails in overcoming friction ; the weight of the car multiplied by the co-efficient of traction multiplied by the velocity of the car.

In determining the power required, it is usual to allow from ten to fifteen horse power per car as a maximum for small roads ; and where there are many cars supplied by the same station as low as seven or eight. It will be less than double per car for trailers.

Knowing the power required along the line, and its general distribution, we can then estimate the most advisable cross-sections of trolley lines and feeders, and their dispositions, as we shall presently consider.

The copper required for feeders and trolley line is a matter of considerable expense. Nevertheless, as they are practically uninjured by time, and the life of the latter is very long, estimated on good authority to exceed twenty years, the running expenses for this portion of the equipment are very light, the charge going against interest on capital account.

Let us consider the electrical conditions of the line which determine the dimensions of feeders and trolley line.

First, then, what does the service demand of the line ? Two things : that the pressure shall not vary much on it, being kept up to the standard for the system ; and that it shall carry sufficient current for all the cars in use without excessive waste in heating.

The generators at the power station are supposed to keep the initial pressure in the lines practically constant. We will calculate, then, the necessary conductivity of the line to meet the above conditions.

Required to find the resistance of a line supplying current for a number of cars along it, given the total allowable drop and the initial pressure. See Fig. 18.

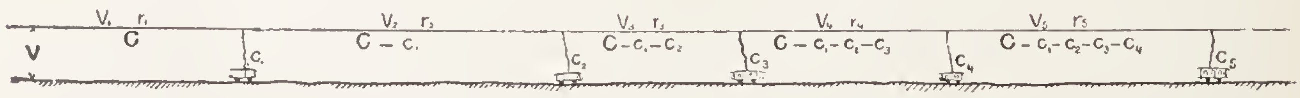

Fig. 18.

Let $C$ = total current supplied.

$c_1$ = current passing through 1st car.

$c_2$ = " " " 2nd car, etc.

$V'$ = total drop allowed on line.

$V_1$ = drop between beginning of line and 1st car.

$V_2$ = " " 1st and 2nd car, etc.

$r_1$ = resistance between beginning of line and 1st car.

$r_2$ = " " 1st and 2nd car, etc.

Then:
$$V' = V_1 + V_2 + V_3 + \ldots$$
$$= Cr_1 + (C - c_1)\, r_2 + (C - c_1 - c_2)\, r_3 + \ldots$$
$$= (c_1 + c_2 + c_3 + \ldots) r_1 + (c_2 + c_3 + c_4 + \ldots) r_2 + (c_3 + c_4 + \ldots)\, r_3 + \ldots$$
$$= c_1\, r_1 + c_2\, (r_1 + r_2) + c_3\, (r_1 + r_2 + r_3) + \ldots$$

Where each one of the co-efficients of the currents $c_1$, $c_2$, $c_3$, etc., $r_1$, $r_1 + r_2$, $r_1 + r_2 + r_3$, etc., is the resistance from the beginning of the line up to the point where the respective currents leave it; or

$V' = C\bar{r}$, where $\bar{r}$ is the resistance up to the electrical centre of gravity. The current leaving the line corresponding to the elementary masses, and the resistances between the points where they leave, and the beginning of the line being the ordinates.

That is, the resistance of the line to the electrical centre of gravity is equal to the allowable drop in potential along the line divided by the total current supplied.

If we suppose that the cars are at an average distance (resistance $r'$), nd are using an average current $c'$, we will have

$$V' = c'\, (r' + 2r' + 3r' + \ldots + nr').$$
$$= c'\, \frac{n\,(n+1)}{2} r'.$$
$$= nc'\, \frac{n+1}{2} r'.$$
$$= C\bar{r}, \text{ where } \bar{r} = \frac{n+1}{2} r';$$ that is half the line, plus half the resistance between two cars. Or we may put it in this form: The total resistance of the line $R = nr' = \dfrac{2}{n+1}\, \dfrac{V'}{c'}$, which depends on the allowable drop of potential, the number of cars, and the current used per car.

As an example, suppose that we wish to ascertain the size of a trolley wire necessary for a section of road, two miles in length, upon which there will be not more than five cars at a time, this will give a six-minute service, at an average speed of eight miles per hour. Suppose that the average horse power per car is ten, which is equivalent to fifteen ampères approximately at 500 volts. Then we have:

$R = \frac{2}{5+1} : \frac{50}{15}$, if we allow a total drop of fifty volts along the line.

$= 1.111$ ohms for two miles, or 10,560 feet.

$= .152$ per 1,000 feet.

An allowance of conductivity of fully twenty per cent. should be made in this in practice to meet extra requirements of the line.

$R = .152 - 20\%$ per 1,000 feet.

$= .122$ per 1,000 feet.

Now, we find from tables that No. 1 B. & S. copper wire has .127 ohms per 1,000 feet, and No. 0 copper wire has .101 ohms per 1,000 feet. Either of which might be chosen, depending on the cost of power, on the one hand, or the value of money invested in line, on the other.

If the road were double-tracked, and therefore there were two trolley wires cross-connected, two wires of half the conductivity each could be used. No. 3 B. & S. has .202 per 1,000 ft., and No. 4 B. & S. has .254 per 1,000 ft. Either of which might be again chosen, depending on the above considerations.

Let us consider the result, $E = C_{\bar{r}}$, as relates to the distribution of cars along the line.

If most of the cars are bunched at the beginning of a line, or if there is a heavy demand for current, due to heavy grades, heavy traffic, etc., then the centre of gravity will also be near the beginning of the line, and therefore $V'$ will be proportionately small. If they are collected at the centre, the centre of gravity will be the same as if they were evenly distributed along it. $V'$ would therefore be the same; but if most current is demanded at the far end of the line, the centre of gravity is shifted towards that end, and the total drop in potential $V'$ will therefore be increased. This distribution of cars must therefore be considered in laying out the line.

Following are a few notes taken from the report of Charles H. Smith, of the committee of the American Street Railway Association, referring to overhead construction. *Electrical World*, October 29th, 1892:

" All well-built lines should be sectioned, and the trolley wire should not be of too great a size, as it would then call for clumsy supports; and as it is not the main current wire, it can be of a smaller size. I would therefore recommend No. 4 B.W.G. silican bronze wire, which affords sufficient carrying capacity, and has great strength and durability.

" Sections should not be of greater length than two miles, and should be separated by trolley breakers, of which there are now a number of good ones in the market. In cities and villages where there is great liability of fires, it would be advisable to put trolley breakers at short intervals. Trolley wire hangers and pull-off brackets should be of the lightest make possible, and still have the required strength and the very best insulation."

"Feed-in taps must not be more than five poles apart, and should take the place of the trolley span wire at that point. They should be of at least No. 0 insulated wire.

"The trolley wire being sectional, it is necessary to run a feeder wire to each section; I would, therefore, recommend that the feeder wire be at least thirty per cent. larger than the occasion demands. It will be found that this is money well invested. The insulation in the feeder wire should be the best that can be procured."

"A cut-out box should be located on the pole at each trolley breaker, and should not carry a fuse. It should have the same wire running through it as there is on the outside. The fuses should be at the station, with ampère meter and cut-out switch for each section. Then, in case of trouble in any section, the location can be easily seen, and that section cut out if necessary until repaired.

"Lightning arresters are of great importance on the line, and I would strongly recommend using them at least every 1,000 feet."

The track as an engineering construction we have not time to deal with here, further than to say that for electrical traction it requires to be much more substantial than for horse or cable systems, and that modern steam railroad practice has many valuable lessons for the electrical street railway engineer.

The bonding of the tracks is that part of the construction which aims at insuring small obstruction to the current in reaching the ground, through which it returns to the power house.

Practice varies as to the means of attaining this end. Some roads bury a wire parallel to and between the tracks with frequent copper connection to the rails. The best construction seems to be the connecting by copper wire successive rails with frequent cross-connections to opposite rails, and also connections at intervals with plates of metal, buried near hydrants or other places where the ground is likely to remain moist. An addition of about twenty per cent. to the conductivity of the overhead system should be made to allow for possible resistance in the ground circuit.

## THE STATION.

This is perhaps the most important part of the whole system, as it is the centre of supply, where mechanical energy is transformed and sent out as electric energy. Everything must go well here, or the effects are at once felt in all parts of the system.

The location of the station is the first important question to settle. This depends on :

(1) It should be as near the centre of the system as possible, so that the copper necessary for feeders may be a minimum.

(2) It should occupy such a position that the cost of carrying fuel to it is as small as possible.

(3) Water should be available for boilers and for condensing purposes.

The cost of handling fuel is considerable. If coal is brought from a distance by train, the best position is where a siding can be had, so that the coal may be dumped or stored within reach of the boilers.

A great deal of water is required for boilers and condensers. City water is far too expensive as a rule. The station should be near a stream, or other unfailing ource of supply.

These conditions often conflict with one another. A central position would often involve an outlay in real estate which would be prohibitive, as well as being out of reach of coal or water. Usually, the most important condition is the supply of fuel, and after that the central position and supply of water are to be considered. A final balance will be obtained, which must depend on the consideration of prime cost and possible saving of running expenses.

The station must be able to supply power for the maximum service. It is advisable also, where possible, that it be provided with an extra amount of equipment to provide for breakdown of individual machines, or their stopping for repairs, for cooling or adjusting bearings, etc.

The requirements of a power station for street railway work differ from those of a plant for any other service, and that on account of the irregularity of the load, its sudden and extreme variations, and the great range of average load to be met, which are severe tests of the working of any machinery. For these reasons strong, substantial machinery must be used, and for steam plant quick regulating engines with efficiency at a wide range of power.

As we have seen before, the power sent out on the line is equal to the product $VC$, where $V$ is the difference of potential between the brushes which is kept practically constant. The work done, then, will vary with $C$ When small current is flowing, little work is being done along the line ; and when a heavy current flows a greater amount of work is being done, so that the amount of work being done is proportional to the readings in the ampère meter. Suppose that the meter stands at 60, that would mean about 40 h.p. being sent out on the line, and rather more that the dynamo was transforming, and that the engine was conveying to it. Now, suppose that this current suddenly increases to 120—as would happen often enough—that would mean that more than 40 h.p. extra was suddenly required of the engine in addition to the 40 it was supplying, which would throw a severe strain on the whole plant concerned.

The boiler capacity should be ample for maximum running requirements, with one or more extra to be used alternately to provide for cleaning and repairing any of them.

High-speed engines, condensing if possible, excepting for large plants, have perhaps given the most satisfaction. The horse power required of them varies greatly at different times, and with wide range of cut-off they can best meet the varying loads ; they have less to get out of order than the slow speed, and the initial cost is less. The high-speed engine, too, allows of less reduction between driving and driven pulleys, which is also desirable.

Condensing engines save about forty per cent. of fuel.

For large plants the generators may be connected in parallel, so that a heavy demand for current in any line may be equalized amongst the generators, and therefore amongst the engines driving them. If the total load rises or falls considerably at any period of the day, then one or more extra engines may be started or stopped, as the case may be, keeping the load on all thus within reasonable limits of their rated capacities ; that is, at those for which they work most efficiently.

In this case slow-speed engines would come into play. Compound engines, too, work efficiently, and even triple expansion ones may be advisable where the total load is large and fairly steady.

Small units in proportion to the total power required are considered best ; this on account of the wide variation of the load at different periods of the day, machines being thrown in or out as required, and also on account of the liability of accidents to the parts. The greater the part of the plant injured, the greater will be the impediment to traffic, and the more difficult will it be to repair.

Large fly wheels—which may be driving wheels at the same time—are an important requirement, as they assist in keeping up the speed when a heavy load is suddenly thrown on until the engine governor has had time to act.

A plan which is often followed is to connect each engine directly by belting to two dynamos with combined capacity equal to that of the engine. This is because an engine is less liable to injury than a dynamo ; and if anything happens one of the dynamos, the engine may run on with the other until the first is repaired.

Counter shafts have been used a great deal, but are being discarded as objectionable. Their advantage was that with a number of engines and generators any engine could be thrown in to work with any of the dynamos. Considerable power, however, is lost in driving the shaft. It occupies considerable floor space, largely increases the quantity of belting used, and the losses connected therewith.

The following is quoted from C. J. Field : "What we want in the generating station for electricity is the smallest division of units, consistent with the safe and economical operation of the station. Each unit should be entirely independent and separate from all other units, thereby increasing the reliability. This cannot be obtained in a safe and economical way by the use of the counter shaft. In railway work with large generators we can see no excuse at the present time for its use. Generators should be belted directly to the engines, whether Corliss or high-speed, or else coupled directly to the engine shaft.

"A type of engine which we believe is going to be largely used on this class of work, as well as lighting work, is one that will come in between the high-speed engine and the Corliss, and which will combine many of the advantages of both. . . . This engine in units of 500 h.p. would run at a rotation speed of 140 or 150 revolutions, and with a piston speed of about 650 to 700.

". . . .Beyond any question, when it comes to this size we have got to come to the Corliss practice of double valve, thereby reducing the clearances and bringing it down to the extent of the Corliss practice. The trouble in this line has been to get electric manufacturing companies to take up the building of large multipolar generators adapted for direct coupling at a speed of from 100 to 200 revolutions. We find that in Europe, where their work has been more special, they have successfully developed this type of engine and generator, and beyond any question it is going to be, both for lighting work and for railway work, the type of unit for central station practice in the future. It means, when the vertical engine is used, the installation of the steam and electric plant in the space formerly used for engines alone. This means reduction in the cost of building, operation, and maintenance."

It may be well to add—from the same source—a table giving the average fuel consumption per horse power, and the cost of the different styles of engine :

| TYPE. | | LBS. COAL PER H. P. HOUR. | COST PER H. P. SIZES OVER 100 H. P. |
|---|---|---|---|
| High speed, | single . . . . . . . . . . . . | 4 to 5 | $11 to $13 |
| " " | compound . . . . . . . . | 3 " 3½ | 14 " 16 |
| " " | comp. cond. . . . . . . . | 2¼ " 2½ | |
| " " | comp. triple . . . . . . | 1¾ " 2 | 18 " 22 |
| Corliss engine, | single . . . . . . . . . . . . | 3½ " 4 | 16 " 18 |
| " " | comp. cond. . . . . . . . | 1⅔ ' 2 | 22 " 25 |
| " " | triple . . . . . . . . . . . . | 1½ " 1⅔ | 27 " 30 |

"The cost of steam plant complete is about \$50 to \$60 per horse power for high-speed, and \$65 to \$75 per horse power for Corliss."

There are four principal types of direct current generators corresponding to the different combinations of field and armature. They are.:

(1) Field excited from separate source.

(2) The series dynamo where fields and armature (and external circuit) are connected in series so that the same current passes through all.

(3) The shunt dynamo; in which the fields form a shunt between the brushes of the armature, so that a small part of the total current generated in the armature goes through the fields, and the rest through the external circuit.

(4) The compound dynamo has two sets of windings in the fields, being a combination of (2) and (3).

The dynamo for railway service must be a constant potential machine—that is, with the potential between the brushes constant—and this can only be accomplished for varying loads by having it compounded.

We have $E = V + Cr$, where $E$ is the generated $EMF$, $V$ the potential between the brushes, $C$ the current and the resistance of the dynamo between the brushes, so that when there is an increase of current $E$ must be increased to keep $V$ constant. Now, in the compound machine the shunt winding supplies the part $V$ and the series coils, by carrying the total current, increase the field strength, and the generated $EMF$ proportionally to that current, and equal to the product $Cr$, or within a reasonable difference from it if correctly designed.

A rheostat is usually placed in series with the shunt field in order to regulate $V$ as desired. Throwing in or taking out extra resistance decreases or increases the current flowing through the shunt field, decreasing or increasing the generated $EMF$.

Injury may happen to a generator from the following electrical causes:

Too large a current flowing—due to (1) too many cars being supplied; or (2) a short circuit to ground, either through car or any point on the line—may cause the overheating or burning out of the armature, or injury to the commutator.

Too high a potential difference—due to (*a*) too great a rate of revolution of the armature (due, perhaps, to the engine failing to govern quickly enough after a heavy load is thrown off); or (*b*) too great field strength (due, perhaps, to there being not enough resistance in the rheostat of the shunt field)—may cause the puncturing—that is, the current jumping across from one wire to another at a point of weak insulation, or from a wire to the metal of the machine—of the armature, or of the shunt field, or may cause the overheating or partial burning out of the shunt field.

The machine should be well insulated from ground to prevent this puncturing between the conductors and the metal of the machine. It should also be done for the safety of the attendant, who is liable to touch the metal of the machine and the positive brush at the same time.

The interior arrangement of the station should be made with an eye to simplicity, and ready accessibility to all parts; the engines, generators, switch board, etc., being all in sight, so that if any part is not working properly it may be detected at once and remedied, if possible.

The switch board should provide:

(1) That any dynamo can be thrown in or out of use at pleasure by means of a single cut-out.

(2) That the total load required from the station may be equalized amongst any number of the dynamos. This is done by connecting the positive wires to a bus bar.

(3) That in case a dangerous current is flowing through any dynamo it may cut itself out automatically. There are various forms of automatic circuit breakers for this purpose. A spring released by an electro-magnet when the current reaches a certain limit throws the circuit open.

(4) That any feeder may be thrown in or cut out at pleasure by means of a single switch.

(5) That any feeder may be cut out automatically when too great a current is passing out to it. As the line cannot be injured by this excessive current, the circuit breaker should be so regulated as not to throw for any possible current on the line which is used by the cars, but only in the case of short circuits to prevent waste or too great a strain thrown on the generating plant.

(6) That each dynamo circuit should have a current meter to show how much each is supplying, and whether they are properly equalized or not.

(7) That each line should also have a current meter.

(8) That the potential of any machine or that between a bus bar and ground may be determined at any time. One or more volt meters are used for this purpose. They are needed for the individual machines, to make sure that they are running at the right pressure before they are thrown into parallel with the others on the bus bar.

It is advisable also to have an auxiliary bus bar with which lines may be connected at pleasure, upon which it is desirable to have a higher pressure than for the rest of the system; this is sometimes necessary for lines reaching distant parts. It should be possible to connect any dynamos to this auxiliary bus. It may be advisable to increase their potential to from 550 to 600 volts. This may be done by rheostat regulation or increase of speed of armature.

Lightning arresters should be placed on all feeders entering the station.

# SOME EXPERIENCES WITH A CANADIAN TURBINE IN AUSTRIA.

By H. E. T. Haultain, Grad. S. P. S.

Mr. President and Gentlemen,—It was in the beginning of January, 1890, that I took the position of resident engineer in charge of the ——— mines in Austria, previously having been assistant in the same mines. At that time a small 6-inch "Little Giant Turbine," manufactured, as I saw by the name on it, by some firm in Picton, Canada, had just been put in position. It was placed in the adit level at the foot of the day shaft, and was connected by vertical pipes in the shaft, with a reservoir on the surface; the perpendicular distance between the reservoir and the turbine was 265 feet. The lower 140 feet was of riveted wrought-iron pipes, 9 inches in diameter; the upper 125 feet, and a horizontal distance of 35 feet from the shaft to the reservoir was of plain 5-inch wrought-iron pipes. The connection between the 9-inch and the 5-inch was a cone 5 feet long. The 5-inch pipes happened to be on the mine, consequently they were used as far as they would go, the idea being to increase the whole length to 9-inch, if future developments required it.

The amount of water available was from 30 to 80 cubic feet per minute, according to the season. The turbine was to drive a dynamo by Immisch & Co., of London, capable of converting about 20 horse power into electrical energy. The dynamo was connected by cable along 550 yards of adit level with an Immisch motor, capable of giving out about 16 horse power, which was to drive the pumps and hoisting machinery in the pump shaft. The mine was flooded to adit level, and had to be pumped out to a depth of 120 feet; to this depth the mine contained about 1,000,000 cubic feet of water.

The turbine had been supplied by a London firm of agents to the order of the London office of the mining company, and in supplying the turbine they expressed their inability to give any guarantee as to its working under such a high fall, as they had never had the opportunity of seeing it at work under such circumstances. They calculated that it ought to make about 2,700 revolutions per minute, and for this speed it was geared down by means of a pair of bevel wheels to a counter-shaft which was connected with the dynamo by a leather link belt, the speed of the dynamo being 700 revolutions per minute.

If any one will take the trouble to look in the advertisements of almost any engineering magazine, he will see an engraving of this kind of turbine. It generally works with a vertical axle, and consists of a wheel (in this case 6 inches in diameter) which is as if it were in two stories, the one discharging to the top, the other to the bottom. The wheel is placed in a cast-iron case, which is in the form of a true spiral round the wheel. The water enters the wheel all round its sides, and leaves it at the top and bottom. The case is supplied with a gate which admits the water to both stories of the wheel, or only to the lower half. The whole is self-contained, and is most conveniently connected direct with an iron pipe conveying the water. A box built round it prevents the escape of spray; and this being connected with the tail race, it requires nothing more. It is most suited to falls of from 3 feet up to 50 or 60 feet. It is a remarkably convenient form of turbine, and can be put in position by anybody. But it certainly did seem ridiculous in its position at the bottom of the shaft; the belt connecting it with the dynamo weighed as much as the whole turbine—case and all; and beside the dynamo, which weighed a ton, it looked so small that it went by the name of "The Coffee Mill" among the Austrian workmen. Nevertheless, if we had had sufficient water to supply it fully, it would have driven several such dynamos; the trouble was that we had so little water that we could only open the gate about ¼ to ½ inch, instead of the 2½ inches it required for the lower half alone.

On inquiring into the matter, I saw that it was quite unsuited for our requirements, and could never be expected to give satisfactory results under such circumstances. When the dynamo and motor were in place, I saw by the reading of the electrical instruments that we could get only some 4 to 8 per cent. of the energy of the water passing through the turbine. Of course something different had to be put in its place, but until that arrived we had to do the best we could. So we placed a block of wood in the lower compartment of the turbine, blocking most of the spiral space round the wheel, and admitting the water to somewhat less than one-quarter of its circumference. A convenient thaw gave us plenty of working water, and as in the beginning the pumps had light work we succeeded in getting along all right.

The choice of the new wheel was left to me, and an advertisement was placed in an English engineering magazine. I wrote for catalogues and estimates to many places in England, Germany, Austria, and Switzerland, and went here and there examining turbines at work under various circumstances, but none that I saw had such a high fall as ours. I received quite a liberal education in the utilization of water power and choice of water motors, and, truly, I saw that it is by mistakes we learn.

The choice lay between a "Partial Girard" by Toelle & Co., of Niederschlema, and a Pelton wheel, offered by Hett, of Brigg, England, in answer to our advertisement. That the Pelton was a satisfactory wheel under high falls I knew from the description of the work done by these wheels in the Comstock mines, where they were working under a fall of 1650 feet. The Partial Girard I had seen at work most satisfactorily under falls of about 100 feet, in the valleys of the Erz-Gebirge, driving pulp and paper mills. The Pelton wheel could be delivered at the mine in about five weeks, the Partial Girard not under two months, so we chose the Pelton wheel.

I used to live alone in a disused stamps' house situated in the valley below the mine, and one night about three o'clock I heard steps coming stealthily along the stamps' house to my room I jumped out of bed, grabbed a big heavy oak stick I had brought from England with me, and waited to see what was going to happen. I was much relieved to hear the voice of the night-shift machineman asking me to come underground, as the turbine was acting very strangely.

I blessed that turbine in two languages, dressed myself, and went underground in a very bad temper. The turbine had already cost me hours and hours of worry and trouble and patient toil, because it was always getting out of order on account of the vibration of the cogwheel going its 2,700 revolutions per minute (and sometimes as high as 3,300).

I had always to attend to this kind of work myself, and it was no joke, I assure you. When I got underground the turbine was making about as unearthly a noise as I ever heard.

The assistant machineman, a stolid German, had given the thing up as a bad job, and was quietly smoking 'Die verdammde Kaffee Mühle" was all he remarked. I shut off the water, determined that the turbine should not work any more in that place, and left the men to take it to pieces. They found that the block of wood inside had become loose and was jammed hard against the wheel—hard enough to reduce its speed to about 1,000 revolutions per minute and to absorb most of the power. Fortunately, the Pelton wheel arrived in a few days, and it was immediately put in place.

The way we all blessed that Pelton wheel, stood round it, and watched it by the hour, would have made a stranger think we had gone mad, or had found a new god. For nearly two months we had been continually worried and bothered to our wits' end over this "Coffee Mill"; it very seldom went for twenty-four hours without the bearings giving way and having to be readjusted. There were four bearings in four feet of shafting, and they, of course, had to be in perfect line; the upper two had been badly made by a local manufacturer, and were extremely difficult to adjust. The turbine was in a low corner of the shaft, where one had to crouch down and crawl about on hands and knees in a place always sopping wet and dripping with oil; the turbine had consumed two kegs of oil in two months. Then, the terriffic noise of the badly-fitting bevel wheels in the confined space made the life of the attendant miserable; but now we had a machine that went at a respectable speed of 600 revolutions per minute, it did not spill a drop of water or oil, and, beyond a slight hissing, it did not make a sound. There was no possibility of its getting out of order, and it gave a proper efficiency.

I made some tests with a Prony brake; and using only about eight to twelve cubic feet of water per minute, it gave an efficiency of about 60 per cent. There is no doubt that when more water was used and the nozzle wider open a considerably higher efficiency would be obtained.

The Little Giant Turbine had had its day underground; it was put in a place it was never designed for, and as a natural result it was a failure that cost considerable time and money.

From this out everything went smoothly underground, and the mine was soon drained.

About 200 yards from the shaft house was the smelting house, and for this we required about two horse power for driving the blast fan and other things. The London office had advised using a thirty-foot water wheel in the shaft house driven by the water before it went down the shaft to the turbine, and then by means of wire rope transmitting the power to the smelting house. When I arrived at the mine the trestles for the wire rope pulleys were already in place, and the water wheel was being constructed. I found it would be cheaper and decidedly more satisfactory to put an electric cable up the shaft, and an electric motor in the smelting house driving it from the Pelton wheel underground. This would have been a permanently satisfactory method, though still not the cheapest.

At this time I received instructions to arrange for the smelting house in the cheapest and most expeditious way possible, without paying much attention to its lasting qualities.

Above the smelting house was a reservoir about fifty feet by thirty feet, and six to ten feet deep; and into this flowed the water that did not go down the shaft to the Pelton wheel. The reservoir was about sixty feet higher then the smelting house, and now that the mine was drained and the pumps going only occasionally we could depend upon about fifty or sixty cubic feet of water per minute for three or four days at a time, and this was as long as the smelting generally lasted, so I decided to put the

"Little Giant Turbine" in the smelting house. The problem now was, what connection should I use between the turbine and the reservoir, which was 100 yards away?

The foreman assured me that there would be no difficulty in getting a man to bore logs of wood four yards long with a six-inch bore. We were surrounded by woods, and wood was cheap, so this seemed the most advisable way. We ordered our logs ten to thirteen inches in diameter, to be free from knots, and gave special instructions for them to be delivered with the bark on.

The foreman said he would get the man to do the boring; there were lots of men who did nothing else but bore logs for irrigating the fields. The logs arrived, but *without* the bark, and the man who had engaged to bore them suddenly found out he could not bore a six-inch hole; no, nor five inches either; nothing bigger than three inches. We hunted through village after village—the villages are all just about two miles apart from each other up there—but could not find a man who could tackle a five-inch bore. Here was I in a nice fix—the logs bought and *paid* for, and all drying and splitting without their bark on; the ore waiting to be smelted; pay day coming round and no money for wages; everything at a standstill for want of a borer. At last we found a man who possessed a 3½-inch borer, and another man who could use it, and professed to be able to use a five-inch borer made by a blacksmith in the neighborhood. If you take an incomplete hollow cone five inches in diameter at its base, and two inches at the top, and split it lengthways in half, one of these halves would be like this five-inch borer.

The new professed borer and an assistant, working at the extravagant pay of fifty cents a day (the average miner only getting thirty cents a day), with a promise of a bonus if he finished within a given time, started in fairly with his 3½-inch borer at the rate of about five logs a day, and my spirits rose again. After he had finished four or five, I thought I should like to see him try his hand on the five-inch borer. He sharpened it up well and began, and he and his assistant struggled away at it till the perspiration poured down their faces. At the end of about half an hour, they had only succeded in enlarging the 3½-inch hole to five inches for a distance of about six inches. The blacksmith who had made the borer was called in and sworn at; he guaranteed to make the borer all right, and next day they tried again, with no better luck, and the professed borer coolly informed me it could not be done, and that there was nobody in the Erz-Gebirge who could bore those logs with a five-inch bore.

The foreman came, and I blessed him for having assured me the thing could be done so easily; he lost his head, and intimated that I was a fool for not being satisfied with a 3½ bore; as if water could not run *down hill* through a 3½-inch pipe!

I had several times been on the point of ordering wrought-iron pipes up from Prague; but now, having got so far, I was bound I was going to put those logs in even if we had to cut them up in short pieces and dig them out with a gouge.

All of a sudden I received an inspiration, simple enough, but still an inspiration. I caught sight of a disused hand-hoisting gear which had two cogwheels, about three feet and six inches respectively in diameter. With the help of the blacksmith and carpenter we fixed the large wheel on the five-inch borer, and the small one on a crank handle, and arranged the whole on a sort of sliding table. Then we fastened a rope with a swivel to the end of the five-inch borer and drew the rope through a log that had already been bored by the 3½-inch borer, and fastened the end to a sort of capstan, and put a boy to keep it taut, and thus pull in the borer and keep it well up to its work. All one had to do now was to turn the crank handle, and the five-inch borer got through the wood in fine style. We put the four most active men on the job, and kept it going night and day. On the fourth day we had the satisfaction of seeing the last log finished. But still they were not fit for use, as the five-inch borer did its work very roughly, and the inside of the bore was left covered with big splinters. We had some iron rollers just about the size of the bore, and were able to quickly and thoroughly burn the splinters out with these. The logs were all bound with iron bands made from 1½-inch by ¼-inch iron; those near the reservoir with three bands, and those near the turbine with four bands. The two end bands were plain hoops hammered over the ends, and the middle ones were made with a bolt and nut, and were screwed on hard while hot. The logs were laid in a trench from one to four feet deep, in as straight a line as possible.

In fastening them together, a hoop seven inches in diameter of 1½-inch by ⅛-inch iron was hammered alternately into the two corresponding ends of two logs. It was first fitted to the end of one log by hammering it into the wood to a depth of ¾ of an inch, and was then taken out and carefully fitted in the same way into the other log; so that, when the two ends were placed together, ¾ of an inch of the iron hoop was thus in each log. This made a very simple and satisfactory joint. One of the logs, which had cracked rather badly before boring, split when the water was let in, but two extra bands put on immediately made it all right, for when it was thoroughly wet the cracks closed up.

The connection with the turbine was made with an odd bit of eight-inch cast-iron pipe that happened to be left over from the pumping gear. It fortunately had a flange that could be fitted to the turbine, and the end of the last log was pared down to fit into the end of it which had no flange. At the reservoir end a "gate" made out of the top of a stove was fitted to slide up and down on the end of the log, and an old beer tap was let into the log just below the reservoir to let the air out or in, according as the water was let in or out.

The turbine was geared to run at about 1,000 revolutions per minute, and everything worked perfectly smoothly. The smelting was begun immediately, and directly the metal began running properly samples were sent off to dealers in Vienna, Prague, and Berlin, asking for their bid. Answers were received by telegram, and the metal, which was of a remarkably good quality, was shipped off to the highest bidder in Vienna by express, and was paid for cash on delivery, just in time to meet the wages.

Of course there was considerable loss in the pipes, but still we had quite sufficient power for what we wanted.

Connected with the turbine, but never all going at the same time, were the blast fan, a pair of crushing rolls, a set of three small slag stamps, a heavy end-shove concentrating table, and a set of vibrating sieves. All the counter-shafting, belting, and gearing were made out of odds and ends lying about on the mine; several of the pulleys were made of wood by the carpenter, and some of the bearings were of beech. Not a thing but the logs and the iron for binding and connecting them was bought; the highest wages received by any of the men on the job was that of the head carpenter, who got forty guldens or sixteen dollars a month. So I think I fulfilled my instructions to do the job in the cheapest and most expeditious manner possible.

To those who have been accustomed to seeing turbines and other machinery easily and comfortably put in place by ordinary workmen, and to seeing logs bored out for pumps, etc., as an everyday occurence, it probably seems strange that an engineer should attempt to waste the time of a scientific society in describing these clumsy efforts about an apparently simple makeshift. But there is the point—it was a *simple makeshift*.

Plans had been drawn up by the resident engineer, under the instructions of the London office—which seemed very nice from simply the engineer's point of view—for a thirty-foot water wheel and transmission by wire ropes for a distance of 200 yards. Plans had been drawn up and approved of for meeting the same end very neatly and more cheaply by electricity, using the Pelton wheel in the shaft as the motive power. This was highly satisfactory, and would have been so permanently, whereas the turbine in the smelting house must be only temporary, because the water supplying it would later on be required for the Pelton wheel to furnish power for the hoisting machinery. With the electrical plan, all one had to do was to order the machinery, drop it into place when it arrived, and *pay;* but there was the trouble—the *paying.*

I give you this as a true bit of experience—as an experience that impressed itself very strongly on my mind, and which, I feel confident, has played an important part in my education; simply because it was rough, clumsy, simple, a makeshift, in a place where everything that I expected and desired was the opposite.

FREIBERG, SAXONY, December, 1892.

# NORTH BAY WATERWORKS.

By T. R. Deacon, P.L.S., Grad. S.P.S.

The town of North Bay, population 2,500, stands on a neck of land about two and three-quarter miles wide, which forms the height of land between the waters flowing into the Georgian Bay *via* Lake Nipissing and the French River, and those flowing into the Ottawa River *via* the Mattawa River. The geological formation is Laurentian, the rock being chiefly gneissoid granite and quartzite of an extremely hard nature. As the town is quite young, it being only nine years since the first house was built in that locality, though a very important point as a railroad town, and, at present supported by little agriculture or mining, the town fathers thought that it would be unwise to go to any very great expense in the construction of a waterworks system.

The services of John Galt, C. E., of Toronto, were obtained as consulting and chief engineer ; and, under his direction, a careful examination was made of each of the different sources of supply.

The first scheme considered was to obtain water by gravitation from Chippewa Creek, above the falls on the same, at a point about two and a half miles north of the town, where an elevation of some 215 feet could be got. This would have been the most desirable system, as, though the first cost might have been greater, still, no machinery, fuel, or storage tank, would have been required. And I may say here that for these and many other reasons, wherever practicable, a gravity system is always the best. However, the Provincial Board of Health condemned the water absolutely, as unfit for domestic purposes, owing to certain organic impurities in it. The scheme was therefore abandoned, as the cost of constructing filters and purifiers, such as would have been required, rendered the scheme impracticable.

The next proposition examined was one to gravitate water from Trout Lake (a lake about nine miles long, and three-quarters of a mile wide ; the head waters of the Mattawa River, two and three-quarter miles northeast of the town) into a storage basin, near the town, and then pump it into an elevated storage tank. The lake had an elevation of about twenty feet above Lake Nipissing ; but, after an examination of the country between, it was found to be impracticable owing to the intervention of a wide ridge of almost solid rock, about 2,000 feet in width, and having a maximum elevation of nearly sixty feet above Trout Lake. The water in Trout Lake was of a better quality than that in Lake Nipissing, and would have been more desirable for domestic use. It might have been obtained by pumping, but only at a very heavy cost, as it would have required two and three-quarter miles of pipe to be laid through a piece of country covered with dense bush growing on a light layer of soil, underlaid for almost the whole distance by hard Laurentian rock, besides having either to cross or get around a deep muddy lake and a boggy marsh. This was beyond the financial resources of the town.

It was finally decided to use Lake Nipissing as the source of supply, as the water was of a fairly good quality. This being settled, Mr. Galt designed a very simple and efficient system, capable of being used either as a storage or a direct pumping system. A point was selected at the extreme western end of the town where the conditions were most favorable for obtaining an abundant supply of good water, unaffected by sewage from the town, and there the pumping station was erected. A twelve-inch cast iron conduit pipe, 585 feet long, with flexible joints where necessary, was laid out into the lake. The conduit was laid in one day and a half. The weather was fine and calm; and, as the shore end had been excavated for and laid, the remainder was put together, one length at a time, on a flat raft of timber; and, as each joint was made, the raft was pushed out from under it, the pipe sliding on wooden rollers. The pipe was suspended from tripods of 4 x 4 inch scantling, with feet of bits of plank to keep the legs from sinking in the clay bottom. The tripod was placed over the pipe, and the one and a quarter inch rope made fast and twisted up tight with a stick before the raft was shoved out from under the end of the pipe. When the special casting for the intake end had been put on, and everything made ready, the whole length was lowered gradually by untwisting all the ropes at the same time, till the conduit rested evenly and firmly along its whole length upon the bed of the lake.

A neat and commodious pumping station was built of brick and stone, consisting of the boiler room, pump room, dwelling, and, underneath the dwelling part, a large room, 32 x 25 feet, in which to place dynamos for electric lighting. The dwelling for the engineer consisted of seven large rooms, with hall and stairway; a balcony in the rear looking out over the lake. The pump, made by the Kerr Engine Co., of Walkerville, was of the Worthington pattern; compound, duplex, and direct acting, of one million gallons capacity per twenty-four hours. The boiler was a sixty horse power, double return, multi-tubular steel boiler, five and a half feet in diameter, ten feet long, and three-eighths of an inch thick, with a single thirty-six-inch flue, and fifty three-and-a-half-inch return tubes arranged around the sides; the products of combustion being discharged into the chimney through a tunnel under the boiler, thus sending them out at as low a temperature as is consistent with a good draught. When all connections were made and steam turned on, the pumping machinery worked beautifully and smoothly. The pump was provided with an automatic cut-off, to prevent overflowing the tank. When the pressure in the pump rose to the pressure due to the elevation of the tank, plus the head due to friction, by means of a piston loaded with a weight, a sliding rod was moved that shut off the steam and stopped the pump. The pump was also provided with revolution counter, time clock, water gauges, steam gauges, etc.; and was very complete. From the pump, which had a ten-inch discharge, the water flowed into a ten-inch main leading down to the more thickly populated parts of the town, where it was distributed through eight, six, and four inch mains, according to the requirements of the several localities ; while an eight-inch pipe led to the elevated storage tank, placed on a high elevation at the northern end of the town. This was one of Mr. Galt's patent storage tanks, and has several important improvements over the ones designed for the Essex and Amherstburg systems, drawings of which were shown in a paper read by Mr. A. T. Laing, and published in last year's pamphlet by the Society. The whole structure consisted of a masonry tower, sixty feet high above ground, with substantial stone foundation placed six feet underground, and laid in cement mortar. The masonry was twenty-one feet external diameter at the top, circular in form, and varying in thickness from five and a half feet at the surface of the ground to two and a half feet at the top, the internal face being perpendicular. Upon this is placed a steel tank, twenty feet in diameter, and twenty-eight feet high, with an inverted conical bottom. The base of the cone is sixteen feet in diameter ; two feet of the bottom of the tank, all round, being horizontal, and resting on the masonry, as shown in the accompanying sketch (Fig 19). The tank was provided with overflow pipe, and had a capacity of 60,000 gallons.

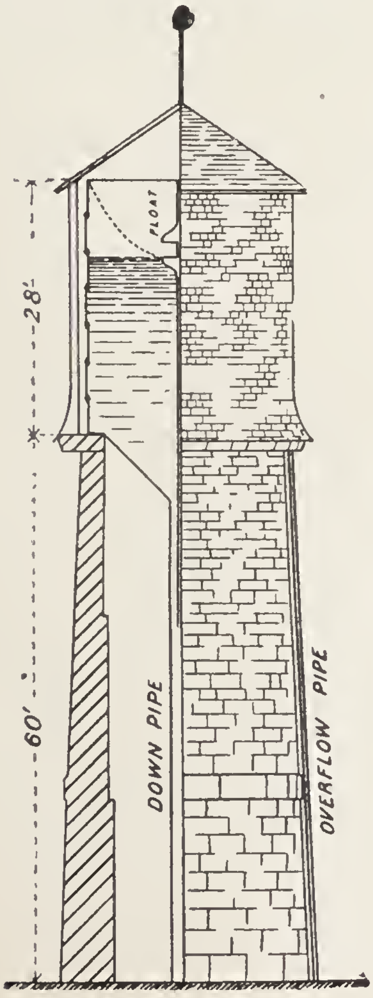

Fig. 19.

You will notice that this tank does not rest on brackets, and that the masonry tower is circular in form.

Owing to the difficulty in obtaining brick at North Bay, the contractors were allowed to build the whole structure of stone instead ; and, as good stone was difficult to get also, constant attention was required to prevent the use of bad stone in the work ; and, even then, as good results as wished for were not obtained in the appearance and finish of the tower.

The pipes used were from the Canada Pipe Foundry, of Hamilton, and proved to be of very good quality. I examined them nearly every time a pipe was cut, besides having them all sounded, and found them very free from blowholes or flaws. Of course, some of them were bad and had to be condemned; but, as a whole, they were a good lot of pipe.

In putting together cast-iron water pipe, the joints are made by first placing the spigot end of the pipe in the bell end of the last pipe laid, and shoving it home with a pinch bar until it is tight up to the shoulder inside. Then a gasket of oakum is wound round the spigot end, and with a thin, flat steel chisel or "yarning iron," as the tool is called, it is driven in tight against the shoulder inside to prevent the molten lead from running into the inside of the pipe. A piece of rope covered with clay is then wound round the pipe and pressed up against the end of the bell, leaving a small space on the top of the pipe for pouring the lead into the joint. When the lead has been poured, the clay is at once removed; and, with a steel caulking iron and hammer, the lead is driven firmly into the joint, making it perfectly water-tight. A joint in a ten-inch pipe ought to stand a tensile pull of, at least, six tons before pulling apart; in fact, if the pipes are good and the joint is well made, the more they are pulled the tighter they get. The amount of lead required in a joint may be roughly stated as one and a half pounds of lead per inch in diameter of the pipe, and costs about three or four cents per pound. No joint should ever be passed about which there is the least doubt. All interested should be sure, before it is covered up, that it is absolutely water-tight and will stand any pressure the pipes themselves will stand; say, 300 pounds per square inch of hydraulic pressure.

The hydrants used were similar in design to the Toronto hydrants, but scarcely so heavy. They were placed from about 300 to 500 feet apart, according to the locality, being closer together in the business portion of the town. There were thirty-six in the whole system. Valves, sixteen in all, were placed at different points along the mains, and upon all branches from all the larger mains, to allow for repairs or extensions being made to any part of the system without disturbing the rest. There is a good deal of rock in the streets of North Bay, and it is exceedingly hard, so that considerable blasting was required. The pipes were laid at a depth of 5½ feet below the street grade, and covered with soft earth to within two feet of the top; the remainder of the trench being filled up with finely broken rock and sand mixed together. Steam drills of the Rand pattern were used, the steam being supplied from a small upright boiler to the drill through a 1¾-inch hose. There were two drills used, and each would drive about seventy-four feet per day of ten hours, the hole driven being about two inches in diameter. The holes had to be drilled about every fifteen inches apart and seven feet deep. In blasting, it was found advantageous to use dynamite containing seventy-five per cent. of nitro-glycerine for the first two or three feet in the bottom of the hole, and then a few sticks of fifty per cent. on top, the rock being hard to shatter. Fifty per cent. dynamite was used altogether at first, but did not do good work. When the works were finished a trial test was made, under Mr. Galt's supervision, in the presence of the majority of the council and a large number of the citizens, with very gratifying results ; water being easily thrown over the highest hotels, churches, and other buildings in the town, from the tank pressure alone. The valve on the main leading to the tank was then closed, and a direct pumping test made. When the pressure at the pump end was raised to 140 pounds per square inch, the water was thrown vertically from the hose nozzles until it separated into finely-divided spray at an elevation of about 100 feet, as nearly as could be judged. A few days afterwards, a fire occurred in a row of old wooden buildings which, it had been predicted, time and again, could never be saved should fire get into them. In six minutes the firemen had three streams playing on the fire, and completely extinguished it without any of the houses being rendered entirely uninhabitable, except for the water. The system was put in at the very small total cost of a little over $29,000, and has proved, so far, a gratifying success. The Canadian Pacific Railway Co. has large shops here, as North Bay is the headquarters for the "Soo" branch, and for a division of 125 miles each way, east and west. It is also the northern terminus of the Grand Trunk Railway from Toronto. Both these companies take water from the town for all purposes.

# AN EXPLORATORY TRIP THROUGH THE ROCKIES.

By L. B. Stewart, P.L.S., D.L.S.

According to previous agreement our party met together at Morley on July 3rd. Morley is situated within a few miles of the Rockies, close to the Stoney Indian reserve, and consists of an Indian mission and a trading post. It is thus a convenient starting point for an expedition into the mountains, as everything needful can be procured there—supplies, horses, and guides. The Indians here have possession of one of the most beautiful spots in the territories. Their reserve occupies the Bow River valley extending from Morley to the base of the mountains. The valley is three or four miles in width, and is flanked by hills several hundred feet in height, from which it appears to be a level plain, with the river meandering through it, but a closer inspection shows that it rises in a series of terraces from the river. This terrace formation is observable in the valleys of many of our western rivers, and seems to point to the fact that their channels at one time must have been much wider than at present, the water being dammed up by some obstruction below, and allowed to subside suddenly at long intervals by the breaking away of a portion of the obstruction. This theory is borne out by the fact that the Bow valley is dotted over with "islands"—as they are called—or high isolated hills covered with large Douglas fir; probably these were at one time actual islands, in a lake-like expansion of the river.

After spending a few days at Morley in purchasing supplies and horses and engaging guides, we finally started on the 8th of July Our party numbered seven, including our two guides, each man being provided with a saddle horse, and we had besides six pack horses, so that ours was quite an imposing "outfit"—to use a western term. Horses, or Indian ponies, in that part of the world cost from $20 to $30, and can generally be sold at the termination of a trip for about two-thirds of their original price, so that transport is by no means expensive.

We generally travelled for four or five hours without stopping, and would then pitch camp about the middle of the afternoon, thus allowing ourselves time to explore the surrounding country, which we usually did by climbing the nearest hill or mountain that commanded the most extensive view.

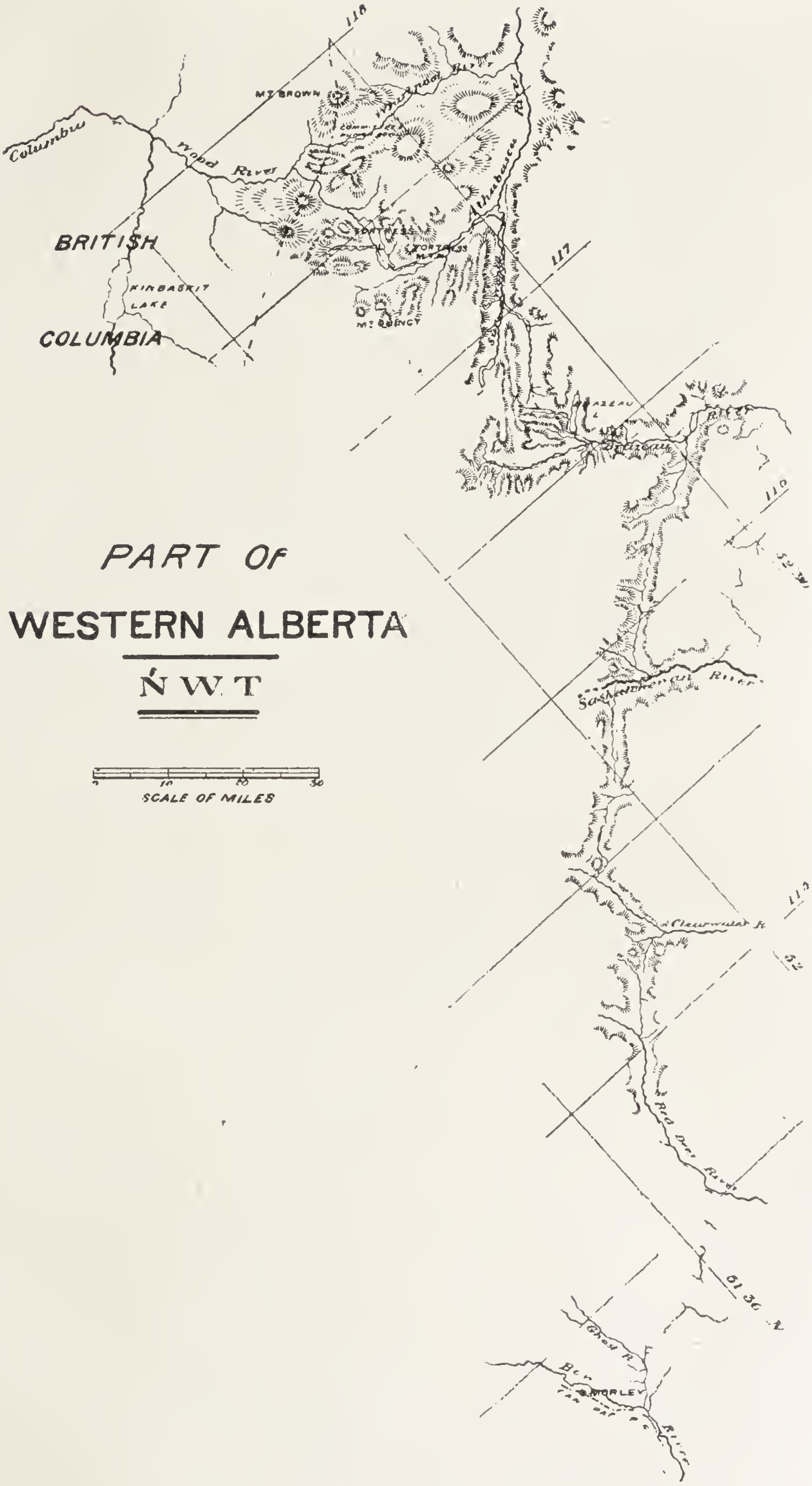

Fig. 20.

For the first three or four days our route lay among the foothills, where the scenery is of a much less rugged nature than that among the mountains proper. Hills they are called only by contrast with the mountains, but they would put to shame many of the so-called mountains in the lower provinces, many of them being 1,000 to 1,500 feet in height above the valleys, and between 5,000 and 6,000 feet above the sea.

On Saturday, July 9th, we reached the Red Deer River, where we prepared to spend Sunday. We were now fairly on our way, and "far from the madding crowd's ignoble strife," in the words of the poet, having left the last outpost of civilization far behind us, and with the prospect before us of meeting with no human beings, except, perhaps, a few roving Indians, and hearing no news of the outside world for at least two months.

We now followed the Red Deer for thirty or forty miles, and on July 12th reached a beautiful spot among the mountains known as the "Mountain Park," at a place where a small tributary enters the main stream. This "park" is a gently undulating plain several square miles in extent, and is rendered all the more beautiful by contrast with the rugged mountains by which it is surrounded; several streams fringed with timber cross it at intervals, and add greatly to the effect. It would be a good location for a small ranch, but would only suit a person who was tired of the world and desirous of retiring into seclusion, as there is no room for a neighbor in that part of the valley.

The following day we packed up and followed the tributary of the Red Deer mentioned above, crossed a height of land, and were soon following a small stream, which led us through a narrow valley, finally, to the Clearwater. Our trail now followed this river for about twenty miles, and then turned sharply to the right and ascended a height of land about 1,500 feet above the river, leading to another valley. That night we camped at about 7,000 feet above the sea; patches of last winter's snow were to be seen in several places, and the night was bitterly cold, but we enjoyed perfect freedom from mosquitoes. These pests are rather numerous in the lower valleys and among the foothills, but they have the good taste to avoid the heights, and they disappear altogether from the mountains early in the fall. Some of us before retiring took the precaution to sew our blankets together in the form of bags, after the manner of Arctic explorers, thus rendering them very much warmer. The next day we pushed on as rapidly as possible, hoping soon to reach a lower altitude, and therefore a higher temperature, and travelled a distance of about thirty miles. It was necessary to make a long move, as our trail led through a narrow thickly-wooded valley, which afforded no food for the horses. We now found ourselves in the valley of the Saskatchewan, though still some miles from the river. We arrived here on Friday, July 15th, and decided to remain till Monday to give our horses a rest, as they were rather used up after the long journeys of the last two days. This gave us an opportunity to explore a little in our neighborhood. The Saskatchewan here flows through a wide open valley, thinly wooded ; one part of it might almost be called a prairie, being quite level, and destitute of trees. It bears evidence, however, of having been wooded at one time, the timber probably having been destroyed by fire. This prairie goes by the name of the Kootanie Plain, from the fact that in years gone by the Kootanie Indians were in the habit of coming here from British Columbia to hunt buffalo. To the north of our camp towered a high mountain, which we named Sentinel Mountain, from the fact that it commands an extensive view in every direction, up several valleys that radiate from that point. Below the Kootanie Plain a large river enters, which the Stoneys call the Hahaseji Wapta, or the Bad Rapids River, and on making its acquaintance in fording we heartily concurred with them in the appropriateness of the name.

This halt of a couple of days I found very acceptable, as I had been walking since I left the Little Red Deer River, about eighteen miles from our starting point. My object in so doing was to test the value of the pedometer in making a tract survey of a country. The plan adopted was to read the pedometer at every point on the trail where its general direction changed, and to take the bearings of the portions of the trail between those points with a prismatic compass. In this way a rough traverse of the route was made, the distances being greatly in excess of the straight-line distances, but latitude determinations, made as often as possible, served to connect the lengths of the courses. Latitude observations can be used as a check on the dead reckoning only when the general direction of the route travelled does not make too large an angle with the meridian. If the general direction is nearly east or west, the method fails altogether, although if portions of the route are nearly north or south the survey of those portions may be used to determine the ratio between the length of a course given by the pedometer and the length in a straight line, and the other courses connected accordingly.

On Monday, July 18th, we moved on, and after travelling about ten miles crossed the river and continued down the left bank until we were again among the foothills. One of the chief objects of our trip was to reach Mounts Brown and Hooker, at the source of the Athabasca River ; but by observation I found that we were already in the latitude of those mountains, and about eighty or ninety miles to the east of them, and our guides were still taking us in a northerly direction. We accordingly held a consultation with them, and by means of a mixture of Cree, Stoney, English, and signs, we found that they had no very clear idea of where we wished to go; but by the aid of a map sketched on a piece of paper we made them understand the direction of our proposed destination.

For the next few days our trail lay among the foothills, keeping parallel to the main range of the mountains—through endless swamps and muskeg, and swarms of mosquitoes, which made us anxious to be again in the cooler atmosphere of the mountains, where we were comparatively free from their attentions.

On Saturday, July 23rd, we reached the Brazeau River, a large tributary of the Saskatchewan, crossed it, and then followed the left bank for ten or twelve miles, and camped for Sunday on a spot of prairie near a small stream flowing into the river. On Sunday Dr. and Mr. Coleman and I climbed to the top of a mountain to the north of our camp, and reached a height of over 9,000 feet. The walking was good, the broken rock affording very good footing, so that in two hours we climbed about 4,000 feet, the height of the summit above our camp. Unfortunately, we were prevented by low-lying clouds from obtaining a very distant view—the object of our ascent—but we caught occasional glimpses through rifts in the clouds of distant snowclad peaks, and we descended to camp satisfied that we were now travelling in the right direction. On Monday we moved on up the river, but were caught in a heavy downpour of rain, which obliged us to pitch camp in a hurry, having travelled only about eight miles.

At this point our difficulties began. Mr. P. was taken ill, and, having learned from our guides that there was a party of Indians on their way to Morley, about a day's journey distant from us, he decided to overtake them and return with them to Morley. The next day he started, accompanied by Jimmy Jacob (one of our guides) and Mr. Coleman, and we promised to remain where we were for a week to allow Mr. C. and Jimmy time to rejoin us, and at the end of that time to move on slowly.

The week was spent rather pleasantly, climbing mountains and exploring the neighborhood, the only drawback being the bulldogs, a species of horsefly, that kept our horses about our camp fire endeavoring to get rid of them, and kept us busy trying to keep the horses away. At the end of a week we began to think of moving, but here we were met by a fresh difficulty. Our remaining guide, Mark Two Young Men, could speak no English, or professed to be entirely ignorant of our language, and we could obtain no information respecting the nature of the country in advance of us, so that we were obliged to ride ahead and choose a camp ground before moving. In this way we moved forward about eighteen miles to a place where the river forks, and here we resolved to remain for a few days to explore. We found that the more northerly branch of the river flows from a lake a few miles above the forks, which we named Brazeau Lake, and on climbing a mountain near us we could follow by the eye the southerly branch for twelve or fifteen miles, until it was lost to view by a bend of the valley. A considerable distance beyond we could see a lofty mountain, capped by a huge mass of ice and snow, and the possibility occurred to us that this might be one of the mountains of which we were in search.

The next day, August 8th, Dr. Coleman and I set out to explore the southerly branch of the river to see if there was any way of reaching this distant mountain. We walked for 18 or 20 miles, and then seeing that we could not accomplish much in one day we returned to camp, and on the following day we saddled our horses, and packed another horse with our blankets and four days' provisions, intending to travel up the river as far as possible in that way, and then send Mark back to our main camp with the horses, with instructions to come for us in four days, and then explore ahead on foot. We were destined, however, not to complete this programme, for after riding about fifteen miles we met Mr. Coleman and Jimmy on their way back to join us, having returned by a different route. They had gained some information at Morley that led us to change our plans; so we turned our horses' heads towards camp again, and arrived early in the afternoon.

Sunrise the next morning saw us all astir, preparing for a move in another direction, and in an hour or two we were again in the saddle. We followed the westerly branch of the river to where it leaves Brazeau Lake, forded it that point, and then skirted the shore of the lake for some miles, to where a torrent enters, which we followed for several miles through a narrow gorge between lofty mountains. We camped that night not far below the line at a height of about 6,900 feet, and on the following morning pushed on up the valley a mile or two, and then turned to the right, crossed a height of land, and soon reached a small stream, flowing in a northwesterly direction. We were now across the watershed that separates the Saskatchewan and the Athabasca systems. Our stream, after flowing about twenty miles, enters another, which, on Saturday, August 13th, brought us to a large river, flowing northwest, which the Indians call the Sun Wapta, and which we decided to be the Athabasca itself. We here spent Sunday, August 14th.

On Monday, as we were packing up, the Indians came to us and began bidding us an affectionate farewell, saying that they were going home, thinking, no doubt, that they had fulfilled their contract. Dr. Coleman produced a copy of their agreement, and explained to them that they had promised to guide us to Mount Brown and back to Morley, and I explained, moreover, that if they did not fulfil their agreement they would be paid nothing on our return. This brought them to time, and they went to work as cheerfully as if nothing had been further from their thoughts than leaving us in the lurch.

We travelled that day about twenty miles, and stopped sooner than we intended, the trail being blocked with fallen timber. We had cleared the trail the next morning, and were preparing to push on, when we found that Mr. Coleman's horse had met with an accident during the night having nearly strangled himself with his tie-rope. As there was a possibility of his recovery, we decided to wait there a day or two.

I then set to work to obtain our geographical position, and found that we were about in the latitude of Mount Brown, and twenty miles east of it, assuming its position on the maps as correct. By climbing a neighboring mountain, we saw a valley extending away to the southwest, through which a river flows, joining the Sun Wapta a few miles below our camp. Anything was better than inaction, so we resolved to explore this valley on foot, taking our blankets and provisions for ten days, and to endeavor to reach our destination in that way. Most of the next day was spent in making preparations, and about 4 p.m. we started, Dr. and Mr. Coleman and myself, leaving Dr. Laird and the Indians in charge of camp. Fording the river in front of camp with horses, and then having driven them back to the other side, we waved a farewell to those in camp and struck into the woods. After a couple of hours' hard scrambling through an exceedingly rough country, we reached the river we had seen joining the Sun Wapta. We had the pleasure of sleeping that night without a tent, but the night was fine, and there were no mosquitoes. The next day we marched on up the river about ten miles ; not a very long day's journey on a good trail, but long enough when one is climbing over fallen timber and up and down cut banks with fifty or sixty pounds on his shoulders.

As the valley of the river now took a turn to the south we were obliged to cross, so we set to work the following morning to build a raft. We cut half-a-dozen logs, a foot in diameter and fifteen or twenty feet in length, and lashed them to cross pieces with ropes, and in a couple of hours from the time we began we were on the other side of the river. We pulled the logs up on the bank of the river to use on our return, shouldered our packs again, and struck into the woods.

On August 20th, we reached a lake about nine miles in length and a mile or two in width, at a distance of about twenty-five miles from our main camp. The scenery here was indescribably grand, the lake was of a beautiful blue-green color, and surrounded by huge mountains, from 10,000 to 12,000 feet in height, surmounted by glaciers. One mountain was particularly striking, bearing a certain resemblance to a huge fortified castle, with round towers and battlements, which we named Fortress Mountain, and the lake we named Fortress Lake. We attempted to climb this mountain to obtain a distant view, but found it impracticable ; so the next day we followed the east shore of the lake for two or three miles, and then ascended along the course of a stream into a valley above tree line, lying between two mountain ridges. Following the ascent of the valley, we soon found ourselves on a ridge overlooking another valley, from which we obtained quite an extensive view. To the west and northwest the mountains appeared comparatively low, while to the west and southwest towered a succession of lofty snowclad peaks, and we concluded that Mount Brown most probably lay in that direction. One mountain to the south of us appeared considerably higher than its neighbors, and a rough triangulation placed it at a distance of thirteen or fourteen miles, and its height at a trifle over 12,000 feet. We resolved to reach this mountain, and, if it were not either Brown or Hooker, we expected at least to obtain a view of those mountains from its summit. Before descending, we moved to another spot from which we could get a good view of Fortress Lake. On the opposite side a mountain torrent could be seen entering the lake and giving its blue-green waters a milky hue, showing its source to be a glacier. The gorge through which it flowed seemed the most practicable route to the distant peak ; so, on the following morning, we built a raft and paddled to the mouth of the torrent, preferring that mode of travelling to making our way through the dense forest that surrounded the lake. Here we camped for the night, making our bed, as usual, under the widest spreading tree we could find ; and the next day, having cached all of our property that could be dispensed with for a few days, we set out along the course of the torrent, and by the middle of the afternoon reached the glacier from which it takes its rise, issuing from an immense ice cave. We then ascended the glacier to near tree line, and camped at a height of about 7,000 feet under a gnarled and twisted tree, that bore evidence of having braved many a storm. In the morning, after an early breakfast, we set out to climb the glacier ; and after a very difficult and dangerous ascent among crevices, many of them covered with snow that made them doubly dangerous, we reached a bare ridge of rock above the glacier, and at a height of 10,000 feet. By this time a dense fog, accompanied by snow, had arisen, so that we could not see fifty feet ahead of us. We waited for some time, shivering behind a ledge of rock, and in a few minutes the snow stopped falling, but the fog remained. Nothing could be seen beyond the ridge but a sea of fog. By throwing stones over the edge and noting the time it took them to reach the rock below, we found that we were on the verge of a precipice, 700 or 800 feet in height; then as nothing further could be done we returned to camp.

By 11 a.m. the following day, we were again at the top of the ridge, and this time we were fortunate enough to have a perfectly clear day. About two miles to the southwest stood our mountain, separated from us, however, by an impassable valley, several thousand feet in depth, with the precipice to begin with. Here was a disappointment: our mountain stood before us, apparently not a rifle shot away, while it would be necessary to travel at least twenty-five miles in order to reach it; we would be obliged to return to Fortress Lake and ascend the next valley to the west. Any one exploring the Rockies without a guide will often find himself in a predicament similar to that in which we were placed, but probably no guides could have been procured that would have been of any assistance to us; in all probability, we were the first human beings that had ever set foot on that glacier.

Determined not to be beaten, we descended to our camp, packed up hastily, and set out for Fortress Lake, where we arrived in time to make ourselves comfortable for the night. On looking over our supplies, we found that we had only about two days' provisions; so that instead of carrying out the programme indicated above, it was necessary to beat a retreat. It is doubtful if the mountain we saw was one of the mountains we were in search of; but it is certain that if they are as high as they are said to be, we would have been able, at least, to obtain a good view of them from its summit.

With feelings of great disappointment, we prepared to return. The following morning was wet, but in the afternoon it cleared, and we put our raft together and paddled back to the end of the lake, where we spent the night. In the morning we shouldered our packs again for the last time, and by noon reached the point where we had crossed the river on our way up. After lunch, we rebuilt our raft and pushed out into the river. We soon found it useless to attempt to guide the raft in the swift current, and were obliged to let it take its own course, and after an exciting run of two hours we arrived at the spot where we had camped first after leaving the main camp, thus covering in two hours a distance that had required about five on our way up. On landing a distant shout was heard, and on a hill about a quarter of a mile away we saw our two Indians, who had been watching our arrival. They had brought two horses as far as the nature of the country would permit, and we were glad to transfer our loads to the back of one of them, having improvised a pack saddle with our straps. In about an hour we reached camp, where we found Dr. Laird busy preparing supper, to which we did ample justice.

The forenoon of the next day was spent in making preparations for our homeward journey, and in the afternoon we walked a couple of miles down the river to see a very fine canon, through which the river flows in a series of cataracts, making a wild and picturesque scene.

On Monday, August 29th, we began our homeward trip, and, after an uneventful journey of ten days, reached Morley on September 8th, having been away from there two months and two days.

On my return to Toronto, I set to work to make a map of our route from my notes and observations. Having reduced all the latitude observations and those for variation of the compass, I then plotted in the polyconic projection the meridians and parallels of the country traversed, on a scale of five miles to an inch. The position of the starting point was then fixed from the most reliable maps in my possession, and the courses given by the pedometer and compass plotted, the lengths being reduced by one-third. The plotting was continued until the first point whose latitude had been determined was reached. This point was then joined to the starting point by a straight line and the parallel of latitude passing through it drawn ; the intersection of these two lines gave the true position of the terminal point. The plotting of the traverse was then continued to the next point of known latitude, and the above operation repeated. In so doing I merely assumed that the general direction of an extended piece of traverse was correct, although its length might be considerably in error ; this depends upon the assumption that the length of any course in a straight line bears a constant ratio to its length, as given by the pedometer. I found that ratio to be about 6 to 10. After the framework of the map was thus constructed, the topography was easily added from the notes taken on the ground.

# NOTES AND COMMENTS.

The degree of B.A.Sc. is now connected with the post-graduate year of the school.

This degree, besides a regular course in one of the recognized departments of the school, represents an additional year of original research in the various laboratories of the school.

The subjects of study in this year are arranged in the following groups and subdivisions :

A. Astronomy.
Geodesy and Metrology.

B. Architecture.
Strength and Elasticity of Materials.
Hydraulics.
Thermodynamics and Theory of Heat Engines.
Electricity and Magnetism.

C. Industrial Chemistry.
Sanitary and Forensic Chemistry.
Inorganic and Organic Chemistry.

D. Mineralogy and Geology.
Metallurgy and Assaying.

Each student is required to confine his studies during the session to one of the above groups. He is not allowed to take less than two nor more than three of the subdivisions in any group—Inorganic and Organic Chemistry being obligatory on all students who select group C.

It is expected that the men taking up this work will from time to time favor the Society with the results of their investigations in the form of papers and discussions. These are sure to prove of interest and value, not only to students, but equally so to the profession in general.

A distinction has been made in the standing of students at examinations ; successful candidates being now classed as honor men and pass men. This gives permanent recognition of special merit, and promotes thoroughness. Honor graduates also have special privileges in becoming members of the Canadian Society of Civil Engineers—a society which has done much to elevate the engineering profession in this country, and which, we trust, will be well patronized by the members of our Society.

We take the following extract from a letter to the Society by T. Kennard Thomson, C.E., 192 Broadway, New York, September 29th, 1892 :

While our Society is undoubtedly a success, it has not accomplished, as yet, all that I hoped it would. Last winter a graduate wrote me that it had become purely an undergraduate affair. This is not to the advantage of either the graduates or the undergraduates, and I have been wondering how it could be remedied.

The only encouragement you can give an active engineer to contribute papers is to ensure their prompt publication and dissemination. This applies to all engineering societies, and is a well-recognized fact. Will you kindly put a motion to the Society for me, suggesting the advisability of publishing a weekly, or at least a fortnightly, paper, which would contain as much personal news of the movements of our members as possible—noting their change of address, occupation, etc. ; and, in addition, such other matters as is usually found in such a periodical, and contain *all papers read before the Society in full, as soon as read?* This would give absent members a chance to discuss the papers in the following issues, and would probably attract many additional short, but valuable, articles. The papers, with their discussion, could then be published at the end of the year, and would be 100 per cent. more valuable. .

If this paper is started, I should be glad to furnish a leaf out of my own book, showing how I have succeeded in getting situations, having my salary increased, etc. I should also be glad to subscribe for a copy, and pay $5.00 for inserting my business card. I know that the undergraduates have their hands full with the regular studies, but the experience they would gain from editing such a paper would be of infinite value to them.

The preface to our Transactions No. 5 state that some of the papers "elicited lively discussion." To send the papers to the graduates without this discussion is like handing a man a glass of milk with the remark that you have taken all the cream off.

* * * * *

In compliance with Mr. Thomson's request, the matter was brought before the Society, and a committee appointed to enquire into the matter.

This committee, after careful consideration of the question, called for tenders for a monthly publication.

The conclusions arrived at were that, financially, the scheme might probably be carried out, though they were unprepared to say what support it would receive. The chief difficulty in the way was that the "work which would be the outcome of the extra publications—receiving, arranging, and answering correspondence, mailing, proof-reading, etc.—would demand more of the editor's time than the Society could conscientiously ask for."

In regard to discussions on the papers, attempts have been made to put the more important in form for publication, but with little success.

In explanation, it may be stated that no advance sheets of the papers are printed, and accordingly they are not in the hands of the graduates until published at the end of the year ; and the discussion on them is confined to those who are present at the meetings at which the papers are read. These discussions are entirely impromptu, and although interesting at the time are not in suitable form for publication. It has also been found impracticable to collect them afterwards.

The only practicable solution would appear to be more frequent publication, as previously indicated.

This, perhaps, in the near future, the Society may feel itself in a position to undertake. If so, we would ask for the hearty co-operation of the graduates in making it a success.

For the benefit of those who may wish to attend the Society's meetings, we call attention to the fact that the time of meeting has been changed from every second Tuesday to every second Wednesday afternoon. This change was found necessary to suit the regular work of the school.

We are indebted to the Provincial Land Surveyors' Association for their exchange, which contains a number of very valuable papers by prominent members of that society, which has now been incorporated as the Ontario Land Surveyors' Association—a step in the right direction, and which must be heartily commended.

## Note on the Brake Dynamometer in use in the Engineering Laboratory of The School of Practical Science.

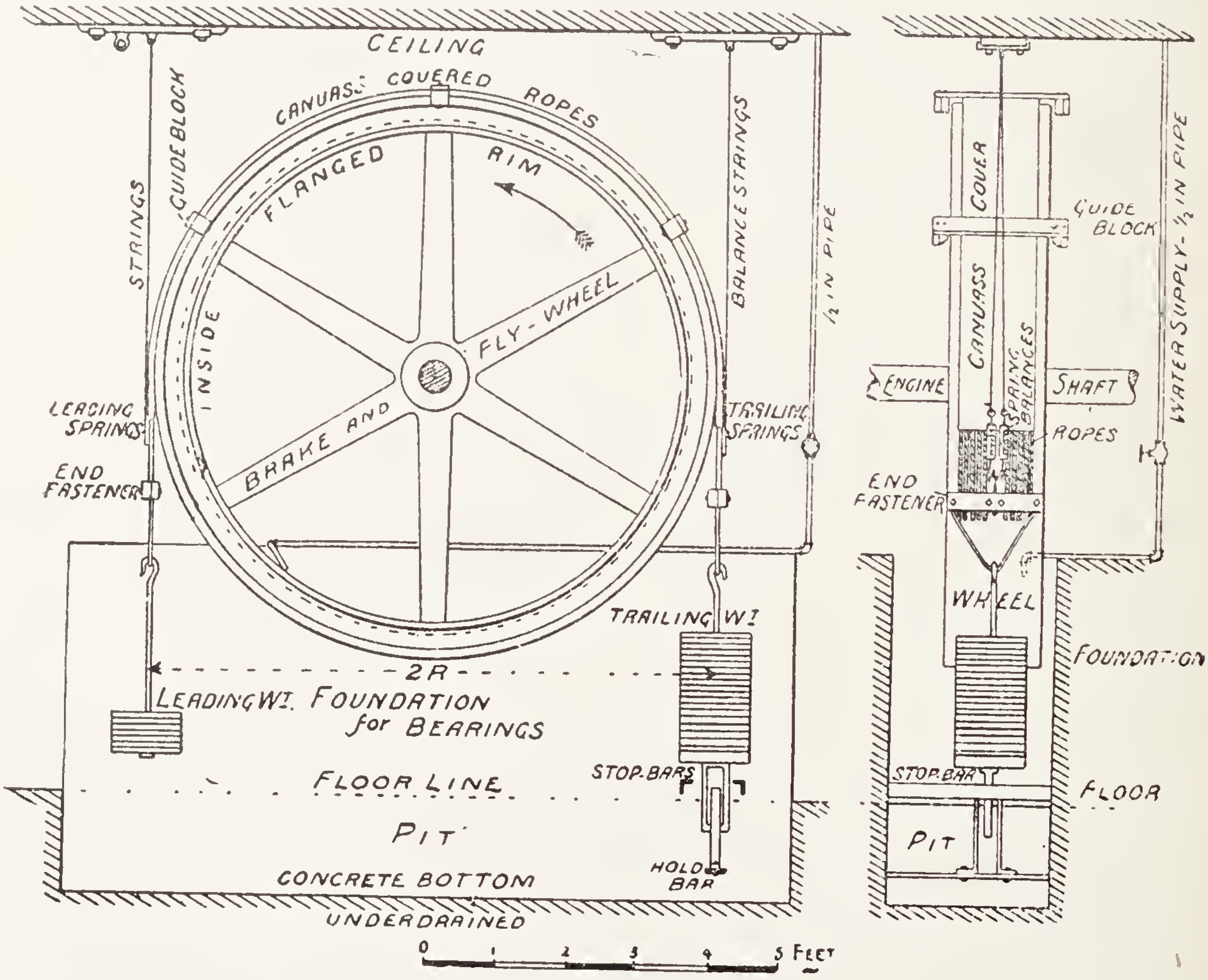

Fig. 21.

This brake, which was designed to determine the work done by a fifty horse power experimental engine, has given such satisfactory results in use, and shown so great a durability with the little attention required, that a brief description of its construction, with a few words on points of special interest, is given here.

The cast-iron brake-wheel is also the fly-wheel of the engine, being mounted directly on the crank-shaft, and is heavy, especially in the rim, which is flanged inside so as to retain the cooling water when the wheel is in motion. The brake-strap consists of ten lengths of ¾-inch manilla hemp rope fastened at the ends by wooden clamps, so that there are five lengths close together on either side of the centre of the brake-wheel, which is crown-faced. These ropes are covered by No. 3 schooner sail canvas, which is folded lengthwise over the ropes and stitched on the back, and held in place by being tied with cord to the three wooden guide blocks. The friction necessary for the conversion of power is obtained between the surface of the wheel and the canvas by suspending weights from the end clamps. These weights are made of lead, and are circular discs with a slot to the centre like the weights of an ordinary weigh-scale, so that they can be easily and centrally put on the hangers. The Salterspring balances which are attached to the end fasteners act contrary to the weights, and serve to equalize and adapt themselves to the slight irregularities which always occur.

In using this brake the trailing end is loaded down, and the total weight noted ; then known weights are put upon the leading hanger till the end clamp on that side is on a level with that on the other side, when the spring balances are hooked in.

The power absorbed by the brake is then proportionate to the difference in tension of the two ends and the speed of the engine. This difference of tension is evidently the reading of the trailing-spring added to the leading weight, and this total taken from the sum of the readings of the leading springs and trailing-weight. The radius $R$, at which this force must be supposed to act so as to give the power, is found by taking half of the measure of the distance between the centres of gravity of the leading and trailing weights, which, if the weights are centrally placed, is the distance between the centres of the hanger rods.

The brake is cooled by admitting water through a pipe on the inside of the rim, and the water is similarly allowed to evaporate, and not drawn off ; the wheel is never allowed to get quite dry inside.

It is interesting to know that although the rubbing surfaces were never lubricated, and though the one piece of canvas may be looked upon as having travelled over 3,000 miles of wheel surface since first put on, with a trailing-weight of about 900 pounds, it is still in splendid condition for use, though somewhat browned, mostly by rust off the wheel face. All the great variations in power caused by non-uniform lubrication of the rubbing surfaces, as well as all the constant attention of proper lubrication, is avoided in this brake ; and when once worn-out the canvas is replaced with little work, and at a trifling expense.

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# PAPERS

READ BEFORE THE

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OF THE

## SCHOOL OF PRACTICAL SCIENCE

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# PREFACE.

Early in the year 1885 the students then in attendance at the School of Practical Science organized the Engineering Society, with Professor Galbraith as president, the objects of the Society being the encouragement of original research in the science of engineering, the preservation and dissemination of the results of such research among its members, and the cultivation of a spirit of mutual assistance among the members in the profession.

Meetings of the Society are held in the School every alternate Wednesday during the session, at which papers on engineering subjects are read and discussed.

This year most of the papers have been presented to us by graduates and members of the profession, and for this kindness the Society desires to thank these gentlemen, and hopes that in the future they may continue to favor us even more than before, as by this means the student is able to gain some information as to the practical execution of work and the means of overcoming the diffculties therein met. But the Society has felt that more papers from its undergraduate members would not only be of great assistance to these gentlemen themselves, but also of great interest to the Society. To encourage this, the council of the School has decided to consider papers read by the students before the Society in the granting of honors at the annual examinations, and we therefore hope to have more undergraduate papers in our next pamphlet.

Hereafter the discussion on papers read will be published along with the papers, which will add greatly to the value of the pamphlet.

At the suggestion of Mr. T. K. Thompson, the dates of graduation of our members are given.

The present edition consists of 1,500 copies, which will be distributed among the members and engineers.

NOVEMBER, 1894.

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Duggan, G. H., M. Can. Soc. C.E., '83.
Dunbar, M.
English, A. B., '90.
Evans, J. W.
Fairbairn, J. M., '93.
Fingland, W., '93.
Forester, C., '93.
Francis, W. J., '93.
Garland, N. L., '90.
Gibson, H. H., O.L.S.
Goldie, A. R., '93.
Hanning, G. F., '89.
Hermon, E. B., O.L.S., D.L.S., '86.
Hutcheson, J., O.L.S., '90.
Innes, W. L., O.L.S., C.E., '90.
Jones, J. E., '94.

Kennedy, J. H., O.L.S., C.E., '82.
Laidlaw, J. T , B,A.Sc., '93.
Laird, R., O.L.S., '86.
Langley, C. E., '92.
Lash, F. L., '93.
Lash, N. M., '94.
Main, W. T., '93.
Marani, V. G., '93.
McAree, J., O.L.S.,D.L.S., B.A.Sc., '82.
McCallum, A. F., '93.
McCullough, A. L., O.L S., '87.
McDougall, J., B.A., '84.
McDowall, R., O.L.S., A.M. Can. Soc. C.E., '88.
McFarlen, G. W., O.L.S., '88.
McFarlen, T. J., '93.
Milne, C. G., B.A.Sc., '92.
Mines, W., '93.
Moore, J. H., O.L.S., '88.
Morris, J. L., C.E., O.L.S , '81.
Nicholson, C. J., '94.
Peddar, J. R., O.L.S., '90.
Playfair, N. L., '92.
Ritchie, N. T., O.L.S.
Roger, J., O.L.S., '87.
Robertson, J. M., '93.
Ross, J. E., O.L.S., '88.
Ross, R. A., '90.
Russell, R., '93.
Russell, W., '91.
Smith, A., '94.
Smith, A. D., '92.
Speller, F. N., B.A.Sc.,'93.
Spotton, A. K., '94.
Stern, E. W., '84.
Taylor, W. V., '93.
Tyrell, H. J., O.L.S., D.L.S., C.E., '83.
Watson, R. B., '93.
White, A. V., '92.
Whitson, J. F., O.L.S.
Wickett, T., '89.
Wickson, T. R., O.L.S.
Wiggins, T. H.,O.L.S., '90.
Withrow, W. J., '90.
Wright, R. T., '94.

## UNDERGRADUATE MEMBERS.

Allan, A. A , '97.
Armstrong. J., '95.
Bain, J. W., '97.
Betty, H. K., '97.
Blackwood, A. E., '95.
Blackwood, C. K., '96.
Black, R. G., '95.
Boswell, E. J., '95.
Brebner, G., '96.
Brodie, W. M., '95.
Brown, R. M., '96.
Campbell, G. M., '96.
Campbell, R. J., '95.
Carpenter, H. S., '96.
Clark, J. T., '95.
Connor, A. W., B.A., '95.
Crews, H. R., '96.
DeCew, J. A., '96.
Dobie, J. S., '95.
Forward, E. A., '96.
Fowler, C. P., '96.
Gray, R. A., '95.
Gurney, W. C., '96.
Guernsey, F. W., '95.
Harkness, A. H., '95.
Harman, O. E., '96.
Hull, H., '95.
Jameson, A. P., '97.
Johnson, G., '96.
King, C. F., '97.
Laing, W. F., '96.
Lawrie, R. R., '96.
MacMurchy, J. A., '96.
Martin, T., '96.
McCullough, A. W., '97.
McGowan, J , B.A., '95.
McKay, W. N., '95.
McKinnon, H., '95.
McPherson, C. W., '95.
Meadows, W. W., '95.
Mollins, C. B., '96.
Moore, I. E., B.A , '95.
Poliwka, H. B., '97.
Pousette, H. R., '96.
Proudfoot, H. W., '96.
Robinson, F. J., '95.
Scott, W. F.
Shipe, E. F., '96.
Shipe, R. R., '96.
Sims, H. B., '95.
Sifton, E. I., '96.
Stacey, G. E , '97.
Stewart, J. A., M.A., '96.
Stocking, F. L., '95.
Troupe, G. E., '95.
Tye, A. T., '95.
Wade, H. R., '96.
Watson, J. W., '96.
Webster, E. B.
Wright, T. D., '96.

# ENGINEERING SOCIETY

OF

# The School of Practical Science

## TORONTO

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## PRESIDENT'S ADDRESS

GENTLEMEN,—I have this afternoon to thank you for the honor you have conferred upon me in electing me as President of this, the representative society of the School of Practical Science. It is an honor of which I am indeed proud, and I am inexpressibly grateful to you for having placed me in the position, which I trust I may be preserved to occupy for the ensuing year.

I feel, gentlemen, that I can hardly fill the office of president as well and ably as my predecessors; but, having the very able and energetic committee that you have elected to assist me, I am confident that the affairs of the Society will be well and zealously guarded.

But, gentlemen, I would have you remember that the success of the Society does not depend solely upon the efforts of the president, or on the work done by the committee, but on the hearty co-operation of the members themselves.

It was my privilege last year to be a member of this Society, while ably presided over by Mr. Lea, and as a freshman I looked up to our friend, Mr. R. W. Thompson, as a gentleman possessed of great executive ability, and envied him the popularity he enjoyed, and so well merited.

Under the presidency of these two gentlemen we have had two unquestionably successful years, due largely to the generalship they displayed in conducting our meetings, and to the lively interest manifested by the students; and I hope, gentlemen, that you will this year take a still greater interest in the welfare of the Society.

On behalf of the Society I welcome those of you who are here for the first time, and to whom a word or two in regard to the working of the Society will not be amiss.

The officers consist of President, Vice-President, Corresponding Secretary, Recording Secretary, Treasurer, Librarian, Graduates' Representative, and one representative from each of the four years.

Meetings are held every second Wednesday during the academic year, at which papers, chiefly on engineering subjects, are read, these papers being published at the end of each year in the form of a pamphlet.

Leading engineering papers and magazines are subscribed for by the Society, and are on file in the library. A large quantity of drafting paper is bought each year and sold to the members by the librarian at cost price. Drawing covers, school colors, etc., will also be supplied by the librarian at the minimum cost.

These, gentlemen, are but insignificant privileges compared to the benefit that accrue to each member as a regular attendant at these meetings.

The object of the Society, according to the constitution, is: (1) The encouragement of original research in the science of engineering; (2) the preservation of the results of such research; (3) the dissemination of these results among its members; and (4) the cultivation of a spirit of mutual assistance among the members of the Society in the practice of the profession of engineering.

In speaking under this head, I think I cannot do better that quote from the speech of a gentleman with whom you are all familiar. Mr. J. A. Duff, a past-president of this Society, in his inaugural address said that, were he called upon to define the great object of this Society, he would say, "It was to afford facilities for and to encourage the development in the minds of its members of habits of reading and observation, and the cultivation of the ability to communicate information thus received by means of writing and speaking."

In previous years, as all the former members of this Society are aware, the fee was $1.00 yearly, collectable by the treasurer in the regular way. Prof. Galbraith, watchful of the best interests of our Society, and anxious as to its prosperity, suggested that it be made compulsory for each regular student to pay a library fee of $1.00 into the school treasury, and each member so doing to be exempt from further dues to the Engineering Society; the greater part of the money so collected, or at least as much as we have ever before raised in a single year, to be handed over to our treasurer to be expended as your committee may deem wise, and the balance to be spent in providing books for the library—the books to be selected by your committee, subject to the approval of the council of the school.

This suggestion met with the approval of your representatives, and a library fee of $1.00 was accordingly inserted in the new calendar, and is being collected with the ordinary fees of the school.

In former years any surplus there was at the end of the year, after the publishing of the pamphlet and paying of current and incidental expenses, was used, if spent at all, to replenish the library shelves.

Therefore, gentlemen, you will easily see that we have everything to gain and nothing to lose by the change just brought about. We will have full control of the library, and must keep it in order. I think, gentlemen, this has been a wise move on the part of your committee, and before many years are passed this Society will possess a well-stocked library and be in a position to profit by the action just taken.

Many of you, no doubt, would like to know why this meeting was not held on Tuesday, as in former years, instead of to-day. During the summer months, when your committee were not here to be consulted, Prof. Galbraith asked me, as the representative of the Engineering Society, if I would consent to allow the day of meeting to be changed from Tuesday to Wednesday, saying, at the same time, that Wednesday would suit the convenience of the majority of the students. After consulting the article relative to meetings in our constitution I readily agreed to his request, and my decision has been sustained by your committee.

I would like to say something in regard to the relation between the Engineering Society and the school itself. Our meetings here, although we control them, are quite part of the work of this institution, and shall, I understand (from good authority), always be regarded as such so long as part of a working day is devoted to them. This Society was instituted eight years ago by Prof. Galbraith, who, for four years, was its very esteemed president, the object being to acquaint the students with the practical side of their chosen profession. I say again, gentlemen, and I cannot impress it upon you too forcibly, our work here as members of this Society is not the least important factor in the curriculum, and I think that students who take the proper view of the matter will appear here as regularly as at lectures.

The success of our Society depends largely on the papers read at these meetings, and the larger the stock your committee has to choose from the better the quality of those selected. As a rule, the papers read here have been written by graduates of the school and outside engineers, and turned over to the corresponding secretary to read. In a few cases have the writers themselves been here to explain points of difficulty, or to answer the numerous questions that may be asked regarding the work covered by the article.

Now, gentlemen, the point which I want to bring out is the advisability of students themselves writing papers. No man who has spent his summer in an office or on construction work has, so far as I can see, any laudable excuse for not writing something for this Society. In fact, gentlemen, I think it is his duty as an active, honest member of this Society to help to supply it with working material. I believe more benefit is derived by the majority of members from a paper written and read by a student than from one by an outside engineer who is not here to take part in any discussion that may arise from the reading of such. Do not misunderstand me, gentlemen; I do not say that students' articles contain as much solid information, or are more cleverly written, than those of outside contributors, but I do say that I sincerely believe that more instruction is gained from them on account of the discussions which are likely to follow their reading. For these reasons, gentlemen, I trust that every member, who can at all, will write a paper for the Society this session. I am not in favor of long papers. I would say, let them be short and to the point, so that we may have several read at each meeting. We have not hitherto confined ourselves strictly to articles on engineering subjects, nor do I think it would be wise to do so, although if we adhere closely to the constitution we shall be prevented from discussing any papers that do not bear on work connected with our profession. I think papers descriptive of a canoe trip, a yachting cruise, or a shooting expedition wedged in with an article on a heavy scientific subject serve to make our meetings more attractive and interesting.

The council of the school are anxious that students should write articles to be read at these meetings. In fact, I may say that they are about to consider the advisability of holding out inducements to encourage men in work of this nature.

This Society has advanced steadily since its formation. Let us this year, by united effort, make the session of 1893-94 famous in its history.

What we want is enthusiasm. Let every man be an enthusiastic member, and our Society will be a success. Do not come here and be satisfied to listen to others take part in discussions and debates. Join in them yourself. If you have an idea you would like to make known, do not be backward in expressing it. If you have a question you would like to ask, ask it. It is in this way that discussions, which add so greatly to the usefulness of our Society, are brought about. Every one of you has ideas which, if imparted to the rest, might be interesting and beneficial. It is in open debate that matters sometimes difficult of comprehension are made clear, and when you have a Society such as this, where the sole object is our mutual benefit, and where our motto should be, "One for all, and all for one," you should not be slow to forward its interests, but do all in your power to enhance its value to yourselves as students.

Our corresponding secretary, Mr. W. A. Bucke, has been alive to the interests of the Society during the summer months. Last spring, before vacation commenced, he obtained permission from your committee to have a circular letter printed, and a copy of this was mailed to all graduates of the School of Practical Science and to the prominent engineers of the province. Several of these gentlemen thus addressed have promised to write us an article on some engineering subject as a result of your corresponding secretary's work in this direction.

I would like to draw attention to a subject which, although not directly concerning the Society, is of interest to students generally, for which reason I feel justified in speaking on it here. I refer, gentlemen, to the Athletic Association of Toronto University, the directorate of which has taken the place of the gymnasium committee of last session. Since this time last year a gymnasium has been established, and has been equipped more fully, perhaps, than any in Canada, and is probably second to none on the continent. For this we have to thank the old gymnasium committee, on which the school was represented by Messrs. Goldie and Rolph, who devoted considerable time to the work in our interests, and the energy and ability that these gentlemen displayed in this connection cannot be overestimated by the students of this institution, and should meet with the thanks of all interested in athletics. As most of you know, when the University authorities erected the gymnasium building, they did so on condition that the students would equip and maintain it. In order to do this a large amount of money had to be subscribed, and I must say, and I am proud to say it, that the students of the School of Practical Science responded generously to the call for funds. I think the gentlemen of the first year may congratulate themselves in being able to enjoy the privileges of the gymnasium provided for them, and should encourage the Athletic Association by giving it their substantial support. We are all aware of the advantages arising from physical culture, and it will not be necessary for me to expound the hackneyed arguments with which you are all so familiar.

Gentlemen, I hope that this may be marked as a most successful year in the history of our Society, and trust that we will not only strive to maintain the reputation of our Society, but shall endeavor to increase its usefulness to ourselves as students.

JAMES D. SHIELDS.

October 17th, 1893.

# PROFESSIONAL PROSPECTS

An address by ALAN MACDOUGALL, Vice-Pres. Can. Soc. C.E., M. Inst. C.E.

It affords me much pleasure to accept your invitation to address you this afternoon in an informal manner. The intercourse between us will be more readily encouraged, and the stiffness which unconsciously creeps in between junior and senior will be relaxed by your custom of inviting some of your professional seniors to visit you. I have tried to exercise my powers of persuasion on Professor Galbraith to have your Society attached to the Canadian Society, but without effect, and from the professor's point of view I daresay he is right, for the existence of this Society leads to closer intercourse amongst all of you who are in daily communication with each other, and from the opportunities afforded by the meetings of your Society many subjects common to you in several parts of your scholastic work can be more freely discussed than if you were part of a large society.

Looking round the country just now, the prospects for the engineer are not particularly bright. Of all professional men the engineer is the first to feel the effects of bad times, for public improvements are classed as luxuries, to be delayed as long as the purse is light. Nevertheless, there is in the country work which is increasing in magnitude—increasing in its ramifications more than in directness of any individual undertakings, and which will, I hope, call for the services of many of you. The work of building up a practice and making a living will be beset by many disappointments, the temptation to pull up stakes will come very often, and there will be many cases in which this may have to be done, whilst in others the race may be for the one who "stays."

Commencing your professional career together, as members of this Engineering Society, you have the foundation of a thorough *ésprit de corps*, which is strengthened to you by your diplomas and degrees. Through this agency you will be able to uphold with befitting dignity the honor of the profession, and each one of you will have to undertake it as a special duty to impress upon the public by your conduct and practice that you thoroughly respect yourselves and the profession you belong to. Our profession has not received the same notice and appreciation from the public which other professions have, but this may be accounted for by the conditions of society and the country. During the early days of settlement every bushwhacker had to be his own road maker and bridge builder ; he had to frame and erect his own buildings ; as his prosperity increased he became set in the habits learned in early life—self-dependence, and possibly the outcome of it, economy. If he were not a Scotsman, he took to the alleged inherited spirit of that nationality and kept a firm grip on the "bawbees." It was almost beyond his comprehension that a man who only looked through a spy glass should claim higher compensation than one who, with his axe, could possibly build a bridge or a barn. Looking back over a quarter of a century's practice in this country, I see immense advances made in the recognition of our profession, which has risen immensely in public estimation since the foundation of the Canadian Society of Civil Engineers, and I am most hopeful of the future, which I believe will be guided and nurtured by concerted action on the part of all members of the profession through the Society.

The main channels of employment in the past have been railway construction, or the public works' service of the Dominion and Provincial Governments. Of later years other branches have opened up, in one of which I am directly interested at present, and which will be one of those cases of "staying" I have already referred to. A movement is spreading through this province for the improvement of our public highways, which is really an extension of the movement so successfully accomplished amongst our neighbors, where the movement for better roads has taken hold of the whole nation from Atlantic to Pacific, and has already caused large mileages of mud roads to be turned into highways passable at all times of the year, and as a consequence raising the values of adjoining lands.

It is the intention of the Canadian Institute, of which body I am the secretary, to call a convention to consider road reform early next February, about the time of the meeting of the Central Farmers' Institute. I am sanguine of the success of that convention. I do not look for immediate improvements in road construction, but I am confident that in the near future there will be work for some of you on the construction and improvement of our highways.

With the advancement of prosperity and the enlightenment of the public, we find the capitalist commencing to lean on the judgment of the engineer for advice in the prosecution of large public works. The professional standing of the engineer is now a guarantee and one of the best recommendations he can have; it is therefore incumbent on him to make himself perfectly familiar with all the details of that special branch in which he practises. This opens up the field for the exercise of individual energy. The mechanical engineer must study out the various methods to obtain the fullest value from raw material. The prime factor of all our mechanical energy—heat—has many an unexplored field. We are still unable to utilize to its fullest development the heat unit of one pound of coal. The steam boiler and steam engine have not arrived at a condition of finished perfection; on land in the stationary and the locomotive engine, and on water in the marine boiler, with its intensely overheated and exhausting stoke hole, a field for improvement and invention is yet open.

In the applications of our newly acquired force—electricity—we have to depend on some other power for its generation, as we have not yet succeeded in abstracting it from the rays of the sun or the atmosphere. The recent discoveries by which electricity can be transmitted to great distances with but trifling loss—I think it is possible to do so now with the loss of only one per cent.—call for thought and attention in its generation. We have an untold amount of power lying idle, and we can say, truly, going to waste, in our magnificent inland rivers. We have in the various chains of lakes which dot our province ample and ready opportunities to store water, which can be let down as required, to maintain any given amount of head; and it does not need much argument to point out to any of you how readily one water power can work in connection with another, generating electricity at this point and sending it so far, till it reaches the current developed at the next point. The discoveries in the field of electrical science follow each other with a rapidity never attained in any other branch of pure or applied science.

These are some of the fields in which your energies have to be developed. I do not wish you to carry away an impression that I have come to speak pleasantries, and make you believe the country is full of work at present. The outline I have given you is a correct statement; the success which will attend you will depend on your individual effort. Let me say one word of warning: let not your youthful elasticity of spirits tempt you to undertake work beyond your powers, for the world has a most uncharitable habit of writing men's failures deeply into its memory.

I doubt not many of you will be anxious to hear a few words from me on the subject I have so much at heart, and on which I have had the pleasure of addressing you on a former occasion. I refer to the position the movement for professional status and close corporation has reached. During the year the committee appointed at the last annual meeting of the Canadian Society of Civil Engineers has been hard at work. As chairman of that committee, I have been in correspondence with a number of leading men in the United States, who are in warm sympathy with the movement, and have received material assistance from members of the profession in the Dominion. There are many obstacles in the way, which will only be overcome by patience and careful consideration of the interests of the profession. Without anticipating the report my committee will make, I may say to you that the proposals outlined in my paper on "Close Corporation," read before the Canadian Society of Civil Engineers, will have to be modified. The movement will be strengthened and established on a firmer basis by prudent action on the part of the profession just now.

# THE REMOVAL AND DESTRUCTION OF GARBAGE

By J. H. Chewett, C.E., A.M. Can. Soc. C.E.

Garbage may be said to consist of (1) House Refuse, made up of ashes, tins, and broken crockery (technically known as "*hard core*"), with animal and vegetable matter, and waste paper, etc. (known as "*soft core*"). (2) Street Sweepings, comprising horse droppings, road grit, pieces of paper, fruit peelings, etc. (3) Trade Refuse, which includes rotten fish, meat, and vegetables, together with waste matters from slaughter houses and markets.

Its satisfactory and sanitary disposal is a question which is at present receiving a great deal of attention in England, and which is most important to large towns like Toronto.

The present mode of disposal widely adopted, filling up hollows and spreading over land, is most condemnable. The future results of this practice are not pleasant to contemplate. Houses built upon such sites will probably be distributing centres for diphtheria and other zymotic diseases. Authentic cases, almost without number, in which this course has proved prejudicial to the health of the locality, are before our eyes. One which might be mentioned is the outbreak of yellow fever in New York at the beginning of this century, and described in the following extract, which is taken from *Scribner's Magazine* of May, 1881:

"The character of the filling, in the extension beyond the water line, is described in an account of a severe epidemic of yellow fever as being a sufficient (and the probable) cause of the outbreak. The slip east of Whitehall was filled with dirt and garbage, and spoiled provisions—even whole carcases of horses and swine were half buried there from time to time, and left to rot under the summer sun. This condition was reformed after the first outbreak, and such excessively foul deposits were confined to the upper end of Front street. The next year the fever made its appearance near this new dumping-ground, and the region of the

Battery was exempt. A very large portion of the river border of the city which has been considerably extended on both sides to about 40th street has been built up with a mixture of sewage deposits, garbage, street dirt, and the composite product of the ash barrel."

There are many records of similar cases, where private houses have been built upon "made ground," containing garbage, and in which sickness and death have resulted, only attributable to the unhealthy emanations that have found entrance to the dwelling.

Most houses are practically ventilators for the subsoil, especially in cold weather, when the inside is at a comparatively high temperature. The tendency of the hot air is to rise and escape through the chimneys and other openings near the roof, and thus when doors and windows are carefully shut to keep out the cold then the new supply of air is drawn through the cracks in the cellar floor. This air has given up a part of its oxygen to oxidize organic materials in the subsoil, and is laden with mephitic gases, which contaminate the foods, and spread disease through the house. These facts emphasize the necessity for concrete or air-tight basement floors, and ventilators to bring pure air from above ground into the cellar.

Dr. Parsons, in his report for 1892 to the Local Government Board of London, enumerates the following diseases, which have been thought capable of being produced by town refuse:

1. General malaise, vomiting, and diarrhœa.
2. Sore throat (follicular tonsillitis).
3. Diphtheria.
4. Enteric fever (in presence of human excreta, especially where water is contaminated).
5. Other infective fevers.
6. Septicæmia.

The substances comprising garbage are practically of no commercial value as garbage, and are such that they cannot safely be trusted in the sewers; nor do they in this thrifty age pay for the disgusting operation of sorting. The days of the "golden dustman" are past.

The collection should, if possible, be made daily; the periods at which it must be removed from private houses must never exceed one week. This work is preferably performed by the municipality, though in some English cities it is still done by contract. The latter course has not, however, given the same satisfaction as the former. The systems of collection adopted vary in different localities. In many of the London parishes each householder is provided with a card upon which is printed a large letter D, and when the dust-bin is full this is exposed in the window of the front room to attract the attention of the scavenger as he passes along the street. In other places calls are made periodically; this is much more satisfactory on account of its being much more systematic.

There are many forms of dust-bins, some of which have the merit of being clean and neat, and at the same time comparatively inexpensive.

Street garbage consists essentially of *horse droppings* and *road grit*, together with other substances of accidental occurrence. The amount of "grit" will depend largely upon the character of the roadbed. Macadam yields a large quantity, stone block and brick less, while wood and asphalt pavements produce practically none. In the main streets the collection and removal should be made two to three times a day, as the constant traffic performs a grinding, and at the same time a stirring-up action, which keeps the fine particles floating in the air. Breathing such an atmosphere is supposed to produce sore throat, and must be highly injurious in any case.

In the crowded thoroughfares of the city of London it would seem almost impossible to keep the streets clean, but the difficulty is very successfully overcome by the employment of boys, who, with a dust-pan and brush, are constantly collecting the horse droppings, etc., in their own particular section. They place these materials in tall cast-iron receivers, which are fixed at intervals along the side of the street, and which are emptied periodically by carts. The boys receive for this work about $4 per week, and the men employed as carters $5 to $6 per week.

Thirty-four carts are used, and, on the average, collect three and a half loads each per day. The number of miles of streets served in this way is, roughly, thirty-eight. The collected refuse is delivered at Lett's wharf in Lambeth, where it is sorted, and part sold to the brick makers and part burnt in destructors.

There are a number of different designs of carts for carrying the garbage to the points of disposal. The usual form adopted is a four-wheeler, some provided with covers, and drawn by one horse.

As before stated, spreading over land has proved most unsatisfactory, so much so that at present there are about fifty towns in England, besides continental cities, which have erected destructors in order to deal with the matter without nuisance.

The form most universally used is that designed by Mr. Fryer, and constructed by the firm of Manlove, Alliot & Fryer, of Nottingham. I have seen several of these in operation, and one in the course of construction, and have selected that of Battersea as typical. The plant, for purposes of description, may be considered as consisting of the destructor, the flue, and the chimney shaft.

The destructor proper is a group of twelve cells, built of brick work and strengthened by iron tie-rods and beams. The number of cells necessary is estimated beforehand by the quantity of garbage to be disposed of. An even number is chosen and placed back to back, with the flue in the middle below their upper ends.

Each cell is twelve feet long, five feet wide at the level of the fire-bars, and three feet three and a half inches high. The top of the cell is a semi-circular reverberatory arch, lined with fire bricks. At the back there is a hearth upon which the materials to be consumed are placed, and from which they pass into the furnace proper. The fire-bars slope forward at an angle of about 20° with the horizontal, in order to facilitate the passage of the clinker and heavy substances to the front. The doors are of boiler-plate and counterbalanced. The top of the destructor forms a flat platform with an opening over the hearth of each cell, into which the refuse is dumped from the collecting carts.

This opening is divided from the opening provided for the exit for the furnace gases by a wall and bridge, built of solid fire brick, to prevent anything falling into the flue immediately beneath. There are also special openings provided for the introduction of infectious mattresses, diseased meat, etc., which fall directly on the burning mass. The platform is approached by an inclined roadway, at the bottom of which is the office, where each load is weighed and where all records are kept.

The flue is semi-circular, being about ten feet wide, six feet high, and fifty feet long. That part between the destructor and chimney is really a double flue, both of which are provided with a Jones' fume cremator. This consists of a reverberatory arch with rings of fire brick placed in the direction of the gases. Ribs of fire brick projecting from the arch serve to deflect the gases upon a mass of red hot coke, which maintains a temperature of from 1000° to 1500 F. This has the effect of breaking up any organic gases which might otherwise be offensive to the neighborhood. Another most interesting feature of the flue is a tubular boiler, twelve feet long by eight feet in diameter. This is capable of producing a pressure of about sixty pounds, sufficient to drive an engine of fifty horse power. The power is used for grinding clinker and other purposes about the works. If the power is not required, it is only necessary to arrange the dampers in such a way that the heated gases pass through the other flue.

The chimney shaft rises 180 feet above the ground level, and rests on a foundation twenty-two feet below the surface, extending five feet into London blue clay. The foundation consists of a bed of Portland cement concrete thirty-five feet square and twelve feet deep, equal to about 900 tons. The base of the footings is twenty-nine and a half feet square, and diminishes to seventeen and a half feet square, which is the size of the shaft at its commencement above the ground level. The shaft is circular, with an outside batter of about one in fifty. The inside, to a height of forty-six feet, is lined with fire brick, with an air space between this lining and the ordinary outside brick. The inside diameter at the bottom is seven and a half feet, narrowing at the top to six feet. Its total weight is 1,850 tons of 2,000 lbs.

In their haste to begin operations this chimney was unfortunately used before the mortar and cement had properly set. The effect of the heat upon it in this state produced a crack, which had to be protected by placing iron bands round it.

As regards the working of the destructor, I cannot describe it better or more concisely than by repeating the rules formulated by Chas. H. Lowe, surveyor to the vestry of St. John, Hampstead. The following are the rules:

### RULES FOR WORKING.

1. Each fireman is required to feed and clinker two furnaces, and run away all ashes and clinkers from same.

2. The fires to be always the same thickness, viz., from twelve to fifteen inches, and the drying hearth to have as much refuse as it is possible to get on to it, care being taken that it is pushed as far into the furnace as possible when charging, and before filling in fresh refuse. The fires must not be in a heap on the side where the gases pass to the main flue, as it is necessary to allow a free draught.

3. Clinkering is necessary when burning the lighter class of refuse, in from half an hour to one hour, and when burning wet refuse a longer time is required.

4. The charging should be done immediately after clinkering, and after the filling in is completed the hopper should be filled up and well trodden in, to prevent the cold air getting into the flue.

5. When the fireman leaves work at the end of his shift, his ash pit should be left free from ashes, and the fires in good condition. At all times the dead plates at the furnace mouths should be kept from hot fire and refuse.

6. The changes in night and day work to take place every fortnight. The night men to clean out the flues and clinker their fires on the

Sunday previous to changing their shifts, instead of working on the Saturday night, and to commence their day shift on Monday; the day men to bank up their fires on Saturday before leaving; on the remaining Saturday night, between the shifts, the night men to work all night and to bank up their fires before leaving on Sunday morning.

7. Nos. 1 and 2 furnaces to be in the exclusive charge of the leading fireman. Each other fireman to take his two furnaces consecutively; that is to say, the man who takes Nos. 3 and 4 furnaces for one week will take Nos. 5 and 6 the following week, and so on.

8. The fires to be clinkered consecutively; that is to say, ten minutes after the clinkering of No. 1 cell the fireman at No. 5 cell is to clinker his fire, and after another interval of ten minutes the firemen at Nos. 3 and 7 cells may clinker their fires. The firemen working Nos. 3 and 4 furnaces, and the firemen at Nos. 7 and 8 furnaces, may clinker both at the same time.

9. The cremator to be kept working night and day by the fireman having charge of Nos. 1 and 2 cells.

By order,

November, 1890. CHAS. H. LOWE, Surveyor.

Having discussed the construction and working, it will be interesting to notice some of the results achieved by destructors.

Each cell will burn from five to six tons per day, without the addition of any carboniferous matter whatever, there being enough of such material in the garbage itself to make it self-consuming. The residue in the shape of clinkers and ash varies from twenty per cent. to thirty-three per cent. This makes an excellent road material, and has been used with great success and profit in tar paving, concrete paving, and silica paving. Battersea realized \$3,815 on clinkers sold for paving purposes in 1892. In this connection it may be said that the population of Battersea is about 150,000. The total cost of collection and disposal amounted to the remarkably low sum of from 35c. to 50c. per ton; and there is no doubt but that this method of disposal could be made self-supporting by careful management; in fact, in Nottingham, Oldham, and Newcastle, the cost was reduced to 10c., 12c., and 15c. respectively.

In Ealing, a town of 45,000, a novel and successful process has been worked by Mr. Jones, the town engineer, and inventor of the fume cremator. The sewage is treated in tanks by the lime and ferrous sulphate process; the precipitated sludge is then mixed with the town garbage and burned. It might be assumed that this would cause a nuisance, but such is not the case. I visited the works twice while the work was in operation, and could not detect any worse odor than that to be found round the average precipitation works.

The steam power is one of the most striking features in connection with the destructor. It is estimated that each cell will burn enough in twenty-four hours to keep a five horse power engine going. The power is used for grinding clinker and supplying electric light in nearly all the works. At Southampton, in addition to this, a thirty horse power boiler pumps 500,000 gallons of sewage effluent for working one of Shone's pneumatic ejectors. At Blackpool it is used for driving electric tram-cars; at Hastings for pumping sea water. Thus we see what valuable work may be extracted from an apparently useless and undoubtedly offensive material.

In conclusion, I would say that it is by some such means as this that garbage should be disposed of. The present mode of spreading over land is a wasteful one; wasteful not only in the loss of work and useful materials, but also of human life, which it is our object and duty as engineers, and especially as sanitary engineers, to preserve by all the means which we have in our power.

# THE BEETON WATERWORKS SYSTEM

By J. R. Pedder, O.L.S.

Mr. President and Gentlemen,—In dealing with this subject, it is my object not only to take it up from a truly engineering standpoint, but also to relate some of the preliminary steps the village took before consulting an engineer, thus forming wrong opinions which the engineer found he was forced to fight against.

Beeton is a village situated in a considerable valley. A little over a mile from the village is a small spring creek with an average flow of about sixty gallons per minute. This creek, being over 160 feet above the village, was considered the best available source of supply, the only obstacle being a range of hills lying between the creek and the village.

In the summer of '92 the question of waterworks was first taken up. The village, thinking they would save the cost of employing an engineer, advertised asking contractors to make an offer to put in a system of waterworks, they to furnish their own plans.

Contractors, of course, like this way of doing work, as the plans they furnish with their contract are generally in such a form that the corporation have not much to hold them by; and as there is not an engineer to inspect the work, the contractor is sure to come out ahead.

In the case of Beeton in the summer of '92, several contractors put in tenders. The most favorable one offered to build a dam at a point where the creek is only 143 feet above, and at a distance of one mile from the village; the dam to be fifteen feet high, and from this the supply mains were to consist of 10″, 8″, 6″, and 4″ pipe, the 10″ not being of any great length.

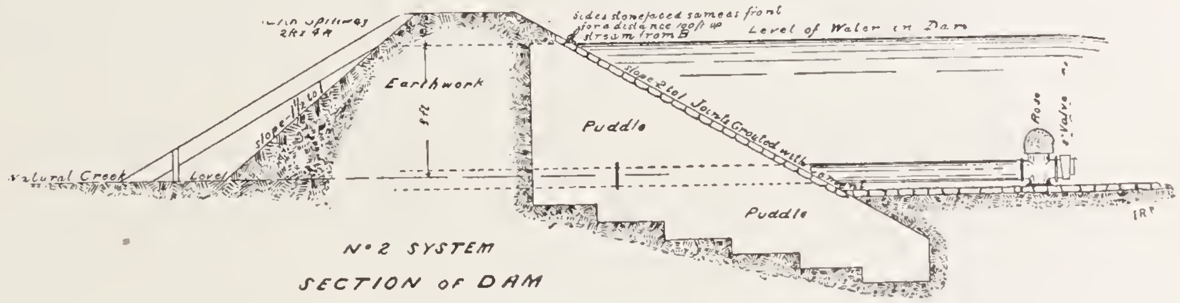
The by-law for this work was carried; but some of the citizens, upon thoroughly investigating the matter, found that the system would not give the service that was desired. A petition was then raised and the by-law quashed.

Shortly after this a very destructive fire occurred, burning out most of the business blocks of the place. This, of course, was a clear proof that they needed an efficient system of waterworks.

The question was again taken up and several engineers communicated with as to the probable amount of their fees, should they be retained. Mr. Galt was finally asked to pay the village a visit to enable him to make a preliminary report, in order that they could have the voice of the people as to whether they wanted waterworks or not. Mr. Galt investigated the probable cost and efficiency of the proposed works as nearly as could be done from the preliminary information which he obtained. He saw from the natural situation of the village that there could be two schemes, which he called No. 1 and No. 2.

His No. 1 scheme proposed having a small coffer dam at the springs in order to collect the water; then to gravitate this water through small pipe into a reservoir or tank on one of the hills near the village.

The No. 2 scheme proposed to build a large dam at the springs, as had been the intention of the village the previous summer; but in Mr. Galt's scheme the pipes were of a larger size, and of a more extended service; the dam also was to be at a point where the creek is 165 feet above the village.



In comparing the two systems, Mr. Galt considered No. 1 the more favorable, as it was the more sanitary, and, if anything, the more efficient; its cost, with a steel tank, being somewhat less than of No. 2.

The two systems were discussed in public, but the idea of the large dam had been so thoroughly ground into the people that they could not see the advantages of the No. 1 system.

The council then passed a resolution accepting the No. 2 system. The by-law was passed, and Mr. Galt engaged to prepare plans, etc. Nearly a week was taken up in acquiring the necessary information in regard to the question of levels and distances. When this information was plotted, it was at once seen that the No. 1 system was to be favored more than ever, especially as a ground reservoir could be formed 2,500 feet nearer the village than the dam would be, and without any appreciable loss of head.

The time was now so limited that it was too late to argue any further with the corporation, and, although it was somewhat irregular for Mr. Galt to do, plans, specifications, and forms of tender were prepared so that the contractors could figure on both systems.

When the tenders were opened, no further argument was needed, as the No. 1 scheme was shown, as Mr. Galt had held from the first, to be the better system by over $2,000. The council then rescinded their former resolution, and decided to accept the No. 1 system.

The tender of McQuillan & Co., of Toronto, for $12,000, was accepted.

Thus, after trying nearly a year to obtain their desired object without professional advice, *the people* were at last put right by retaining an engineer and following his advice.

In the meantime they had paid for taking three votes on the matter, publishing and drawing up the by-law twice, and lost half of the village by fire.

The system as constructed consists of—

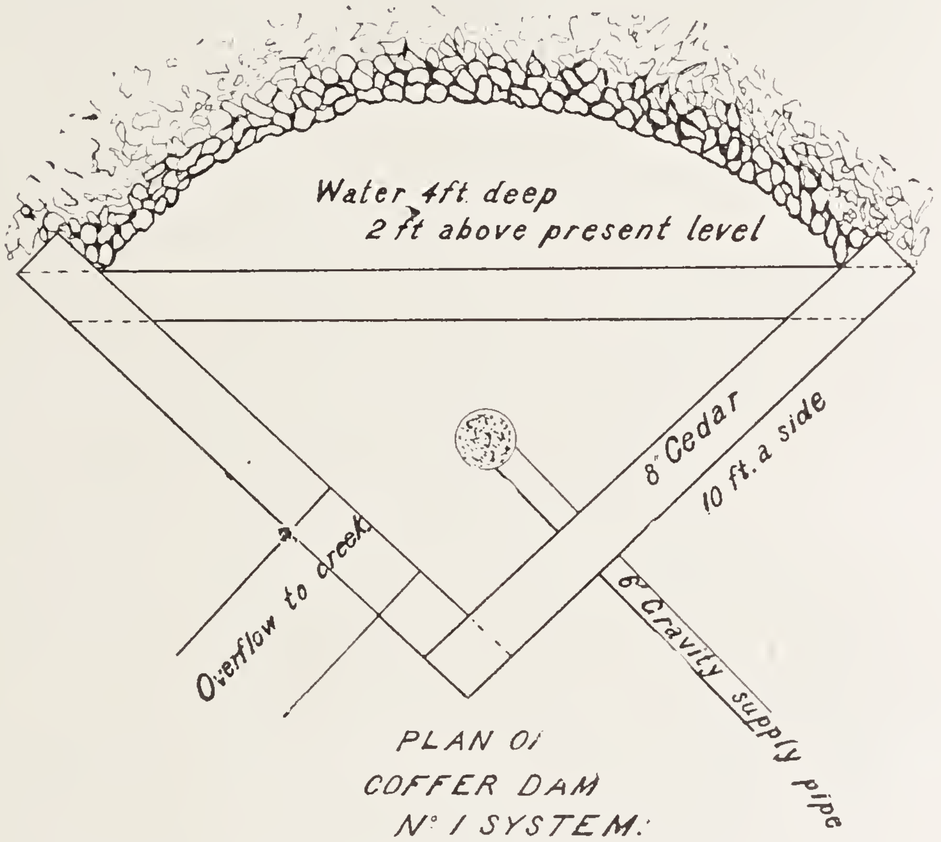
### A—SUPPLY SYSTEM.

One small coffer dam.
500 ft. of 6″ C.I. pipe.
2,000 ft. of 4″ pipe.
2—6″ valves.

### B—DISTRIBUTION SYSTEM.

One storage reservoir—capacity, 140,000 gals.
100 ft. 12″ cast iron pipe.
600 ft. 10″ " " "
5,500 ft. 8″ " " "
5,000 ft. 6″ " " "
800 ft. 4″ " " "
16 hydrants.
1—12 inch valve.
1—10 " "
2—8 " "
3—6 " "

The coffer dam, as shown, is a simple piece of V-shaped cribwork, built of 8″ x 8″ x 10 ft. cedar; the bottom of the dam being two feet lower than the present creek level, and the overflow so placed as to give a depth of four feet of water. On the upper side of the dam a pile of coarse gravel is placed to serve the purpose of arresting any floating substance; a screen is also placed over the end of the pipe to further prevent leaves, etc., entering it.



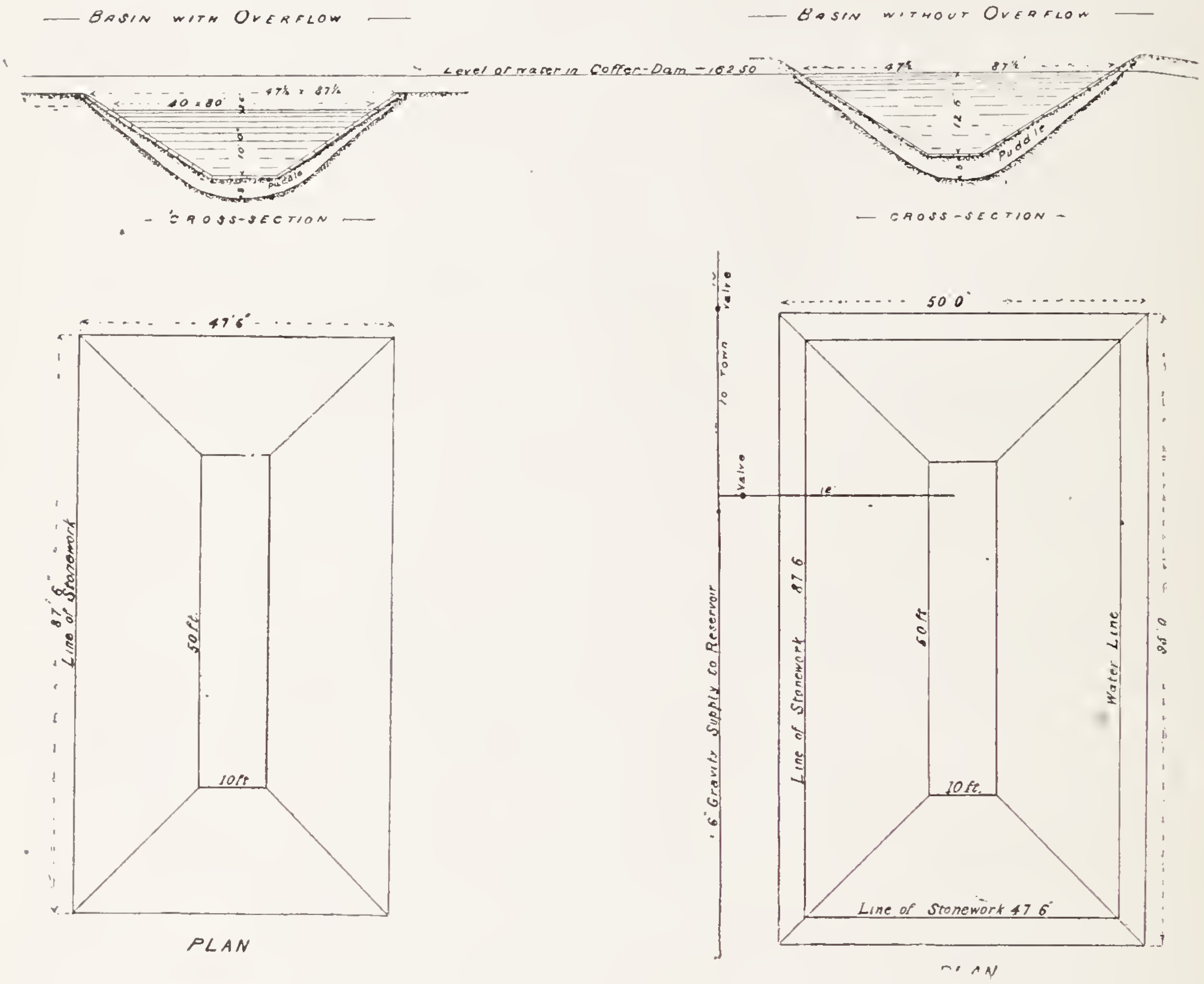
The 6″ and 4″ supply pipe to the reservoir is laid to a grade sufficient to discharge not less than fifty gallons per minute up to a depth of eight feet of water in the reservoir, which, after that height is reached, gradually fills until the level of the coffer dam is reached.

From this it will be seen that after there is eight feet of water in the reservoir, the coffer dam being full, a slight waste of water will occur at the dam, which gradually increases until the water in the reservoir is level with the water in the dam, when the full discharge of the creek will go out the overflow.

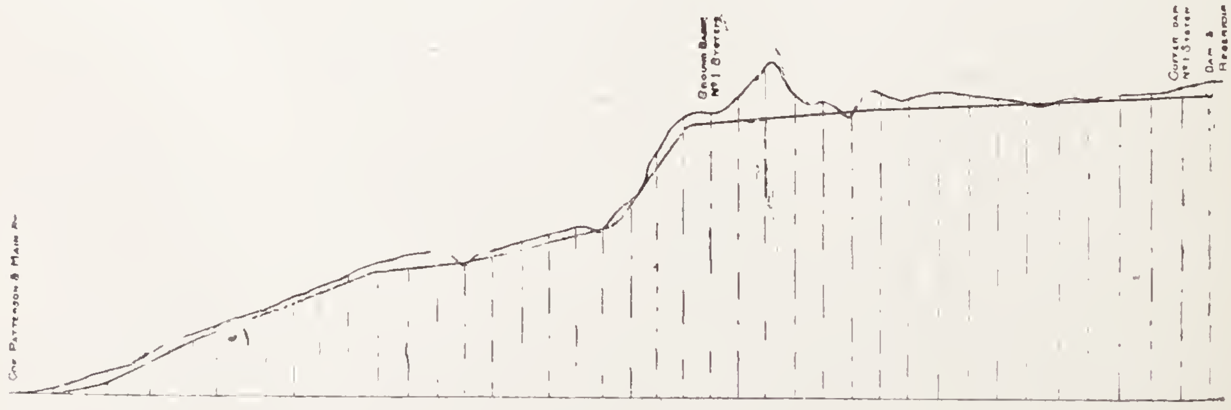
Having any overflow occur at the dam prevents property owners below from claiming as much damages for loss of water as they otherwise would should there be no overflow.

I might here say that when the system was first designed the reservoir was placed low enough so as to have sufficient head to take the fifty gallons per minute until the water reached the overflow of the reservoir.

This, however, has been changed, as is shown on the drawing, the water in the reservoir now rising to same height as water in coffer dam, so that any overflow that will occur at the coffer dam, and the waste water, will go down its natural channel.



The ground basin, or reservoir, has its sides and bottom faced with flat stones grouted with cement. The area of the water surface, when at the same elevation as the water in the coffer dam, is 47½ feet by 87½ feet, with a depth of 12½ feet, the slope being 1½ horizontal to 1 vertical. The basin is located so that one end and part of the two sides are partly embankment, the remainder being excavation. After the proper excavation was made and the embankments built up, the inside of the whole basin



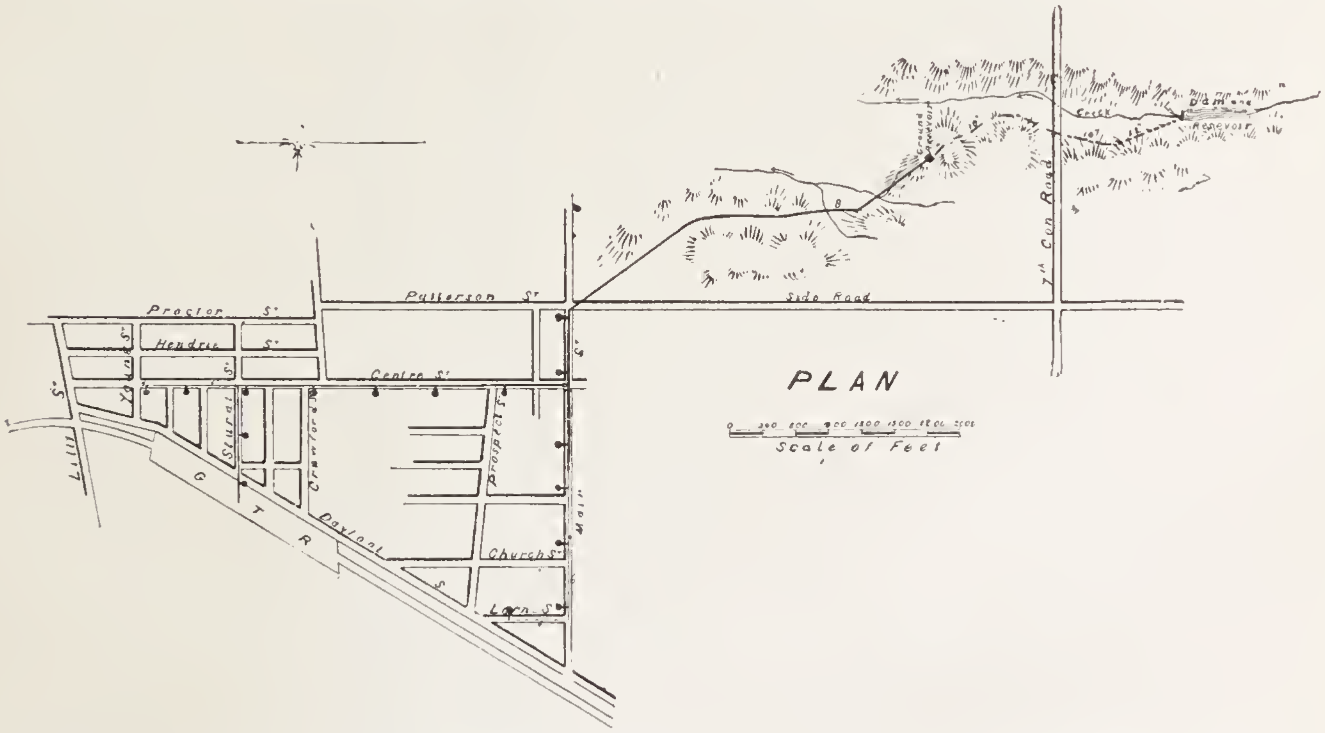
PROFILE

was well puddled before any stones were laid. The elevation of the reservoir above the main part of the village is 162 feet, which will give an hydrostatic pressure of 80 lbs. per square inch, or with three streams, each through 100 feet of 2½ inch hose, one inch nozzle, a hydraulic pressure of 60 lbs. per square inch; or four streams under same conditions, a hydraulic pressure of 55 lbs. per square inch; or five streams under same conditions, a hydraulic pressure of 42 lbs. per square inch, which is ample, considering the possible needs of the village. In fact, this service is about double what is called for by the regulations of the Fire Underwriters' Association; but Mr. Galt considered it would not be wise to design the system to barely pass the above regulations, as the pressure will be greatly reduced during any heavy draw upon the system.

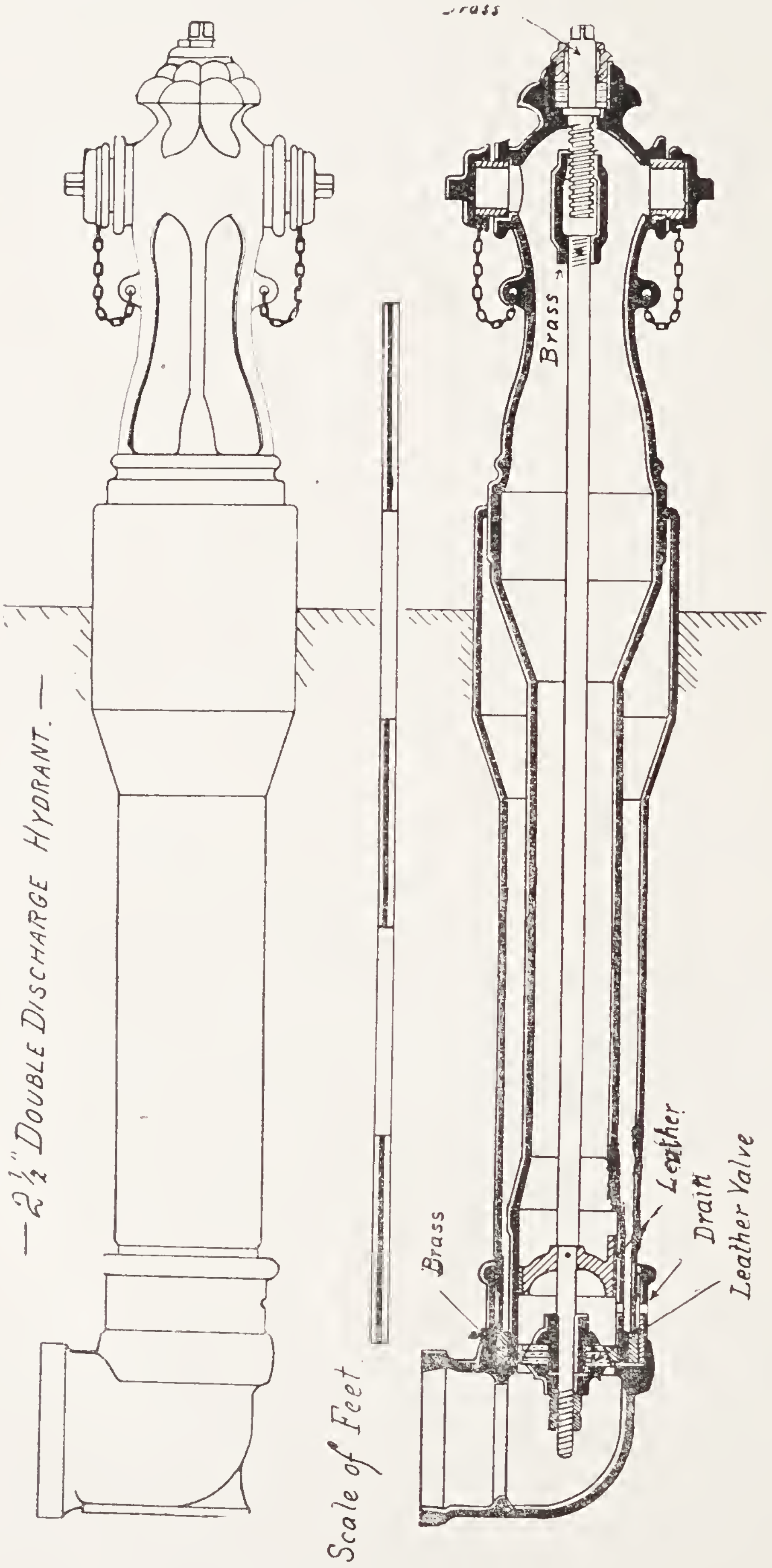
The supply from the reservoir to the village is through 100 feet of 12 inch, 600 feet of 10 inch, and 3,000 feet of 8 inch pipe; these large sizes being necessary in order to lessen the friction as much as possible. As the pressure on the mains can never exceed to any extent 80 lbs., the contractors were allowed the privilege of using pipe a little lighter than the standard weights where pumping is resorted to.

The pipes used were made at Hamilton.

The valves in the village are so arranged that in case of a break as small a portion of the village as possible will be inconvenienced. The valves on the reservoir supply system are so arranged that in the event of emptying the reservoir the coffer dam can be shut off, and in cleaning or repairing the reservoir the water can run from the coffer dam to the village, which, although not being of any great utility, will keep the village from going dry. All valves are provided with cast-iron covers.



The hydrants, as shown in the drawing, are 2½ inch double discharge hydrants of the best Toronto pattern and make, and are all provided with frost-proof jackets.



The trenches have an average depth of five feet, the soil being a sandy clay, easily handled, seventeen men making an average run of 500 feet per day on six-inch main, including refilling. The Provincial Board of Health, in reporting on the quality of the water, classed it as A1, saying it was the best they had examined for some time.

Waterworks may be considered by some an expensive undertaking for a village the size of Beeton, but I think they must be congratulated for the enterprise they have shown, especially as by an arrangement they have made the G.T.R. pays for water to supply their engines a sum annually equal to the interest on the debentures.

I am unable to describe the test, as the works are still under construction, but the system is supposed to be completed before the end of 1893.

# THE CRAWFORD GOLD MINE

J. McAree, B.A.Sc., O.L.S., D.T.S.

This mine, or rather prospect, as it should perhaps strictly be called since it is as yet only in process of development, is situated on the east half of lot 20, in the first concession of Belmont, near the edge of the road allowance on the north side of the lot. The mining property consists of this half lot, together with the mining rights over east half of lot 21, in the first concession, which must be crossed by the vein, as shown by the strike of the latter. The vein has been traced eastwards almost to the county line, a distance of about 1,200 feet; two openings have been made in this part of the vein to the depths of 27 feet and 21 feet, respectively, and the rock assayed, as well as that at the main shaft, at corresponding depths. Five other quartz veins have, I believe, been discovered on the property, all showing more or less gold; and, on one of them, a shaft has been sunk 33 feet. The previous owners of the Crawford have secured the mining rights over lot 20, concession 1, Marmora, lying across the eastern extension of the vein.

The Crawford Mine, as I will designate it, is about 115 miles east of Toronto, and 6 or 7 miles from the village of Marmora, with which there is communication by wagon road. During the past summer, however, the Ontario, Belmont & Northern Railway was laid out and graded from the west half of lot 19, concession 1, Belmont, from the extensive deposit of magnetite there—about three-quarters of a mile from the Crawford—through Marmora township and village, to connect with the Central Ontario and Canadian Pacific Railways, a distance of about 10 miles in all. This road has been bonused by the local government, and, if the bonus be utilized, the road will, of course, be opened to general traffic—and probably will in any event—and then there will be little to desire for the Crawford mining property on the point of facilities for transport, which is, of course, a most important consideration in the cheap working of a mine.

Although Belmont was surveyed so long ago as A.D. 1822, and has had settlements for very many years, yet, owing to its generally rocky character, at least in the eastern part, much of it is still covered with forest, so that wood for fuel, and even timber for construction purposes, is still fairly abundant at reasonable prices ; and, as the price of ordinary labor, as well as of provisions, is comparatively low in this as in other rural parts of Ontario, it is not hazarding too much to say that, perhaps, on no part of the continent could be found a more favorable location for a gold mine.

Regarding the geological system in which the rocks of this section of the country should be classed, there appears to be some diversity of opinion among geologists. By the Geological Survey, it was at first, although provisionally, placed in the Laurentian ; subsequently, however, it was held by some to belong to the Huronian, rather than Laurentian. In a note to Mr. Thomas Macfarlane's report on the geology of this region (see Canadian Geological Survey Report, A.D. 1866), the late Sir W. E. Logan said :—

"The rocks of Marmora, Madoc, and other townships in Hastings, have, provisionally, been classed with the Laurentian series, with which they seem conformable. . . . These Hastings' rocks may be a higher portion of the lower Laurentian series than we have met with elsewhere. It is not to be inferred from the presence in them of a schistose conglomerate that they are therefore Huronian."

In the presence of such eminent geologists who have considered the question, it would perhaps be presumptuous to offer any opinion ; but one thing I would like to remark, without knowing whether the point has already been brought up or not, viz., that the *surface features* of the region, as far as it came under my own observation, resemble those of a Laurentian tract rather than a Huronian. As a rule, the Huronian produces a landscape that is much more rugged, broken, and uneven, with steeper slopes and less flowing outlines, than is presented by a Laurentian landscape.

A notable feature of Belmont is the lake of the same name, in the eastern part of the township ; it receives the waters of Deer River at the north and discharges at the south, being a portion of the system of the Trent. The surface of the lake is about 200 feet below the general level of the country to the west, but on the east the land slopes more gradually. On the west side of the lake, some half mile from the shore, and about half way up to the general level of the country, on lots 20 and 21, in the 4th concession, are some slaty beds, dull green in color, evidently chloritic, standing at high angles, but dipping towards the lake, and with their strike apparently parallel to the general direction of the lake. Some fifty rods higher up the slope, and on lot 21, Mr. Purdy, in digging out the foundation for his barn, took out a considerable quantity of a thin-bedded, dark-gray limestone, in practically horizontal stratification. No fossils were to be seen, but the strata evidently belong to the Cambrian or to the Lower Silurian.

The rock in which the Crawford vein occurs is a moderately coarse and even-grained diorite, consisting normally of a dark-green hornblende with a pale plagioclase. The hornblende is generally in plates and tabular masses, and in prisms which appear to be imbedded in the felspar, as if the latter had crystallized out subsequently to the former. Under the microscope the plagioclase was seen to have been largely altered to epidote. In addition to the two essential constituents, the microscopic section showed masses and lath-shaped crystals of apatite, specks of pyrite and of magnetite, a little biotite, and some grains of titaniferous iron, with borders of leucoxine. I am unable to give the geographical limits of this field of diorite, but may mention that I came across it some three-quarters of a mile south of the mine, also over a mile to the west, and, from information which was given me, I believe it extends a considerable distance to the north and east. The surface is gently rolling, hummocky in places, but nowhere rising into hills ; the general appearance being that of a glaciated surface, although no striæ were seen.

## THE VEIN.

The exploration of this property was begun in A.D. 1891, and, besides the work already referred to, consisted in the commencement of the shaft where work is now going on, and which constitutes the mine. There is erected here a shaft house, and alongside a building containing the steam plant, rock breaker, quartz mills, etc., while conveniently situated are an assay office, blacksmith shop, boarding house, etc. The supply of water is taken from a well sunk near at hand, and there are two reservoirs, one being a large tank placed close beside the smoke stack, and the other one placed close to the other side of the mill house, and half underground. These tanks contain a reserve supply that can be drawn upon in case of a temporary stoppage of the supply from the well. The water is pumped up from the well by a small engine. The water in the reservoir alongside the smoke stack can be heated by an arrangement which applies heat generated by the furnace, and can be substituted in very cold weather for the ordinary water, when there is danger of the formation of ice that would interfere with the proper working of the mill. Up to the time of my visit, however, in the middle of February, it had not been found necessary to draw upon this reserve store of heat, although during the winter there had been some exceptionally severe weather.

The steam plant and machinery, not including the quartz mills, however, came from the establishment of the Waterous Co., Brantford, Ont., and consists of a set of boilers of 65 horse power, with engines of 35 horse power, together with steam pump, hoist in the shaft house, and engine for pumping water from the well.

The ore is conveyed from the shaft house down a slope a distance of about thirty feet to the upper floor of the mill building, and when broken to suitable size is shovelled into a Gates rock crusher, the top of the hopper of which is level with this floor, whence it descends through a spout to the hopper of the Crawford quartz mill, firmly erected on the ground beneath.

The Crawford mill for extracting gold from quartz by wet crushing and amalgamating with mercury was patented by Mr. Middleton Crawford, the proprietor of the Crawford mine, and the following description from the *Engineer and Mining Journal*, July 23rd, 1892, may be of interest:

"The Crawford mill is a new invention, and one which is attracting considerable attention from mining men. As will be seen from the illustrations, it is a variety of the common Ball mill, but one in which the disadvantages of that pulverizer are completely eradicated. It is, in addition, an exceedingly good amalgamator. This mill undoubtedly possesses several novel features, and as a fine crusher has given good results. To pretend that any mill will crush and treat every kind of material is a mistake that has been often made, and in many instances blame has been laid on the machine where it was really due to those employing it. To attempt to crush material finely in one operation is also a great mistake, and wherever attempted has invariably ended in failure. The Crawford mill is pre-eminently a fine crusher, and in order to obtain the best results the material fed into it should be previously reduced by a rock breaker, which is the most economical form of coarse crusher for reducing material down to, say, half-inch to quarter-inch in size.

"The special features of the Crawford mill are: The feed is central, not to one side, thereby insuring an even wear of the roller path. No screens whatever are employed, and a constant source of expense and trouble was thus removed. The crushed material, instead of being discharged at the periphery of the machine, where the swirl is great, passes out in a steady flow near the centre, so that there is no danger, it is claimed, of any particles of gold being carried over with the tailings. A current of clear water is admitted at the centre, passing over the surface of mercury, and rising up through an angular slot below the crushing path of the balls. The action of this rising current of water is to carry off all the material as fast as it is sufficiently finely reduced, and is light enough to pass out at the centre of the machine. Any gold freed from the quartz, or from sulphurets, owing to its greater specific gravity, cannot be lifted by the rising column of water, and sinks down, it is claimed, through the slot below the roller path and becomes amalgamated with the quicksilver in the annular well.

"Further, as the mercury well was out of the swirl of the pulp, and as the water flowing over it keeps any base mineral from coming in contact with it, there is no loss due to 'sickening,' and it is possible in these mills, say the patentees, to treat refractory ores, which could not be treated in an ordinary stamp battery, with copper plates. The mercury is easily withdrawn from time to time to remove any amalgam, and fresh mercury added to the machine by means of the pipe and funnel. In many ores, the ore is so exceedingly finely disseminated that no amount of pulverizing in an ordinary stamp battery can eliminate it from its surrounding matrix. For such ores the Crawford mill is suitable, since by it there is no difficulty in reducing the ore so that it can pass a 120-mesh sieve. Stamps seldom pulverize finer than 40 to 45 mesh. The wearing parts of these machines are rough castings, which can easily be renewed, and at less expense than the dies of ordinary roller mills. These machines are self-contained, easy of transport, and on arrival at the mine can be erected and put to work in a day or two. Clayey ores, which are difficult to treat in a stamp battery owing to the slimes produced, have been very successfully reduced by these mills, little or no gold being carried over with tailings. The following advantages are claimed for the mills :

"1. Minimum outlay in capital.
"2. Great economy in transport and erection.
"3. Low consumption of water.
"4. Small power required for driving.
"5. Extreme fine grinding.
"6. Simplicity of construction.
"7. Ease of management.
"8. Greater efficiency than any other mechanical process.

"The cost of crushing and amalgamating is stated by representatives of the company to be from 60c. to $1.00 per ton, according to the hardness of the ore."

A table is then given showing a comparison of results obtained with this mill with those from stamps, from which it appears that the mill extracted over 30 per cent. more of the gold from ores of certain mines in Canada, the United States, and Queensland than did the stamps; and then the writer continues:

"In addition to this table, which shows the efficiency of the mill, other tests have been made with like results. Thus, at Helena, Mont., the mill extracted $46.00 per ton from an ore where a stamp mill extracted but $21.00. The mill at present is made in two sizes—8 in. and 12 in.—and with a capacity of 2½ tons, and from 8 to 10 tons respectively. The cost of the smaller size is $1,000; of the larger, $2,500. When working, the machine is under lock and key, and one man can attend to at least 12 machines, capable of dealing with a minimum quantity of 100 tons a day."

At the late International Mining Convention in Montreal, Capt. G. Macduff, of Waverley, N.S., presented a paper on this mill, speaking very highly of it. I append two or three extracts from his paper.

"It will not only, as we believe, make mines remunerative which are now abandoned, but it will provide the means for the profitable recovery of gold contained in the large deposits of tailings which have accumulated, and in many instances remain as a bequest from the use of stamps, ordinary mills, or chlorination. . . . In regard to the amount of gold which is obtained by the Plattner process, recently there has been occasion to treat a small amount of slimes sent to the metallurgical works in New York from a large chlorination establishment in Nevada, and the Crawford mill was still able to recover from one sample gold to the value of $8.27 per ton, and from the other $6.20, which had not been saved by the chlorination."

Some failures, however, are recorded against the mill in which it was not able to take out more than a small percentage of the gold from the ore submitted to it. One of these instances occurred in the United States during the past winter, and is referred to in an issue of *The Egineering and Mining Journal* of a few weeks ago. The other instance occurred at the Ogema mine, Black Bay, and was discussed in a Port Arthur newspaper last autumn. In this case the mill extracted all the *free* gold, amounting to about $1.50 per ton, but failed to obtain the portion, amounting to several dollars a ton, that was held by the "sulphurets." The ores of the Black Bay region of Lake Superior are, however, I believe, of a very complicated and refractory character, an example of which is afforded by the Enterprise mine—not working at present. It must be noted also that a subsequent issue of the same Port Arthur newspaper announced that the Crawford mill had been so very successful in some tests made in the Rat Portage country that a quite a number of mills had been ordered for mines out there.

It remains but to add that the larger size of mill weighs but about one ton, and, when taken apart, the heaviest piece can readily be loaded upon an ordinary lumber wagon.

There were two of these mills at the Crawford mine at the time of my visit, a larger and a smaller, only the larger one being running, however. Another large mill is about to be put in.

The shaft, which is ten feet by ten feet, was down 120 feet at the time of my visit, and has, at present, reached a depth of 140 feet. I believe it follows the dip of the vein, which is toward the south, at an angle of about 12° from the vertical. The strike of the vein is about south 72° degrees west. No more stopping was done than just enough to furnish sufficient rock along with that coming from the bottom of the shaft to keep the mill going. The mill puts through about 10 tons in the 24 hours. The water coming into the shaft amounted to about 50 gallons in the hour.

The vein is about four feet wide at the surface, and is somewhat broken up, but becomes well defined as depth is attained. At the bottom of the present working it is about 6 feet wide, and is much more strongly impregnated with the pyrite, being, in fact, about half gangue and half pyrite. The gangue is a white, opaque, vitreous quartz. The pyrite is chiefly massive, but also in grains and in crystals, the larger cubes often showing striated faces, with the striæ on adjacent faces at right angles to each other. Besides the ordinary iron pyrites, there is also a little chalcopyrite occasionally. In the deeper parts of the shaft there is found associated with the pyrite grains and scales of a reddish-brown mineral, which, upon examination, turns out to be iron oxide, or, more properly, jasper. In thin sections, under the microscope, these brownish masses are resolved into aggregations, more or less compact, of minute spherical concretions of ferric oxide and silica, or jasper. The individual sections generally show a system of alternating concentric rings of jasper and quartz, with a quartz nucleus at the centre, the rings of jasper gradually approaching each other towards the circumference of the section, and finally coalescing to form a solid rim, the whole suggesting the idea of a nodule formed on a nucleus of a quartz granule, which received layers of jasper and quartz alternately, the quartz at first predominating, but gradually becoming weaker, and finally giving place entirely to the jasper. The pyrite does not show any definite mode of occurrence in the vein, but will be massed, now towards the foot wall, now towards the hanging wall. The pyrite contains a little magnetite, as is shown when a magnet is passed through a finely pulverized sample.

The hanging wall appears to be simply the diorite changed a little by penetration of quartz, etc., from the vein; a description of a microscopic section is given in the appendix. There seems to be no intermediate layer or selvage between the wall and the gangue; there is therefore no "let go" to the vein, but it is "frozen" to the wall. The foot wall, however, has generally a layer of a chloritic character, which the miners denominate slate, but which has only a very imperfect fissile structure. It consists mainly of chlorite, with quartz, and some calcite. Several "horses" have already been met with in the shaft.

The gold occurs chiefly in the pyrite, but also, to some extent, in the quartz, and "good shows" are constantly being found in both; altogether, however, not much gold is visible, the ore being only low grade.

The average of a number of assays made by me gave about $24 to the ton of 2,000 pounds in gold, the lowest being $10, and the highest $54. A large number of assays, made by a firm in this city, gave about the same average result as the above. A sample of tailings, assayed by the same firm, yielded only a little over a pennyweight of gold to the ton. This does not necessarily prove that the mill is saving all the gold except this small amount, for in the case of the precious metal held by the pyrite a large waste might result from the amount of gold in such a form and fine state of division that it would be carried off in the current of water before it had time to subside and come in contact with the mercury; some recent experiments having shown that gold may exist in such a state of division as to take from five to ten minutes to settle down to the bottom of a beaker of distilled water. I believe the mill extracts about $10 per ton from all the rock put through. The difference between the value indicated by the assays and that actually attained from the mill must be largely due to the mills treating a large amount of poor rock quartz, *e.g.*, which was not represented in the mass that furnished the sample for the assays. A certain allowance must, of course, be made for loss, for it is not even claimed for the mill that it saves *all* the gold. The indications of an assay are valuable for ascertaining the value of a given quantity of rock, only so far, of course, as they represent an average sample of that rock. In the present instance I could not sample the whole mine, but I have obtained sufficient evidence to enable me to say that there is no doubt about this being a valuable property. Even with only one mill running, I understand, it is clearing $40 a day, and when the work is carried on upon a larger scale the profits will naturally be proportionately greater. At present the cost of mining and treating the ore is about six dollars a ton, including all expenses. The gold carries only a small amount of silver—some few pennyweights per ton.

It might be added here that a strong vein of quartz showing free gold was discovered last autumn about three-fourths of a mile south of the Crawford vein, near the south side of lot 19, in the 1st concession. The vein carries pyrite, and very much resembles the Crawford vein; the dip is towards the south, apparently at about the same angle, but the strike, as far as could be ascertained, was about north 70° west; it also is in the diorite.

The deposit of magnetite already referred to as occurring on the west half of lot 19, concession 1, is a very valuable mass of iron ore. Numerous analyses have shown it to be very high in metallic iron, very low in sulphur, and remarkably low in phosphorus. It has been extensively explored with the diamond drill, and it has been estimated that that there are one million tons of ore within one hundred feet of the surface.

In conclusion, attention may be called to the rather noteworthy circumstance that the veins hitherto discovered in the locality that has been under discussion are entirely free from arsenic, which is so prominent a constituent in the veins of the territory immediately to the east, as in Marmora, Madoc, etc.

## APPENDIX.

Containing an account of the examination under the polarizing microscope of the slides, or thin rock sections, made from the Crawford vein, the foot and hanging walls, and the country rock.

### NO. 1.—SECTION OF GANGUE CONTAINING QUARTZ AND PYRITE AND OXIDE OF IRON.

Under the microscope, the above substances occupied the field, the iron oxide being resolved into masses of concretionary nodules, as already explained in describing the gangue; often two or more nodules were seen partially to coalesce.

### NO. 2.—FOOT WALL.

(*a*) Plagioclase, largely changed to epidote.
(*b*) Biotite, dichroic, with inclusions, probably iron oxides.
(*c*) Quartz.
(*d*) Apatite.

(*e*) Specks of magnetite.
(*f*) Chloritic matter.
(*g*) A little orthoclase.
(*h*) Some calcite.

### NO. 3.—HANGING WALL.

(*a*) A good deal of chlorite in fibrous masses, dichroic, green to greenish yellow.
(*b*) Biotite.
(*c*) Quartz.
(*d*) Whitish mass, probably decomposed plagioclase.
(*e*) Plagioclase, changing to epidote.
(*f*) A little magnetite.

### NO. 4.—COUNTRY ROCK.

(*a*) Green hornblende in plates and crystals.
(*b*) Plagioclase, almost entirely altered to epidote.
(*c*) Some pyrite.
(*d*) Apatite.
(*e*) Magnetite.

### NO. 5.—QUARTZ FROM VEIN.

(*a*) Massive quartz with some inclusions; also shows masses and crystals of apatite in colonies.

# NOTES ON CEMENT

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By T. Kennard Thompson, C.E., A.M. Am. Soc. C.E.

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Gentlemen,—The writer, having graduated before the cement testing laboratory was added to the School, found himself put in charge of some masonry construction a few years later with a decidedly limited knowledge of cements, and thinks that he might save the beginner some trouble by giving some of the information he eventually collected from more or less inconvenient sources. To make these notes easier of access, they will be numbered and divided under different headings.

## 1. KIND OF CEMENT.

The first question the writer had to decide was whether Rosendale (or natural) or Portland (an artificial cement) was the better adapted for the work he had on hand. We know, of course, that Portland cement, with the same quantity of sand, will attain its strength quicker, acquire much greater ultimate strength, be less injured by frost, and cost more than Rosendale cement. So it is often a question of economy whether to use Rosendale with a small amount of sand, or Portland with a larger proportion. If the masonry or concrete is to be laid in freezing weather or under water, or where early strength is required to avoid shocks, etc., Portland will be preferred.

## 2. AMERICAN OR EUROPEAN PORTLAND.

The next question is whether it is better to use an American or a higher priced European Portland. At present large quantities of European Portland are imported, but there is no reason why our manufacturers cannot supply us with an equally good material at a much lower price. The writer is confident that if the engineers could always deal directly with the manufacturers there would be much less trouble. Foreign cements are often tightly packed in barrels before being properly seasoned, and we have not the time nor facilities for seasoning cement on the field, though it is often so treated in England, on important works, for ten days or so.

### 3. AIR-SLACKING OR SEASONING.

In Europe cement is sometimes air-slacked by spreading it on the fourth or fifth floor of a building for a few days, then allowing it to fall to the floor below for a few days, and so on until it reaches the ground. This is required where the proportion of clay in the cement is not sufficient to take up all of the lime—a very little free lime is very dangerous—for it will eventually absorb water, expand and crack, or distort the mortar or masonry, and may crumble to dust. If the proportion of free lime is very small it may not take effect for years, but then will have disastrous results.

To illustrate this, the writer knows of a Portland (of course, a bad brand) which has frequently given good results on all the tests, except the hot test, which had not been tried, up to two years, after which the briquettes, both in air and water, suddenly crumbled away to powder. This shows how unreliable is the old method of testing Portland for checking or cracking.

Cement with an excess of free lime is liable to gain its strength very rapidly, and give high tensile tests on a twenty-four-hour test, and ultimately lose their strength instead of increasing it.

### 4. BAGS VERSUS BARRELS.

Paper bags have many advantages over barrels for shipping cement, as they are much cheaper in first cost and are destroyed after using once —as barrels often are, too—and they give the cement more chance to be properly seasoned than barrels. They also afford an easy and accurate means of measuring the proportion of cement to sand, and can be handled more cheaply in many places than barrels.

### 5. TIME OF DELIVERY.

The cement should be delivered on the ground as early as possible, so that ample time will be had for testing, and if it is necessary to reject the first lot the work will not be delayed by waiting to have it replaced.

### 6. NUMBER OF SAMPLES.

There is much difference of opinion as to how many samples should be taken ; but if in a carload a sample taken from every fiftieth bag or tenth barrel is found satisfactory, the carload may be safely accepted. But if some samples turn out good and some bad, it would be necessary to test every package to be sure of the quality. The writer does not believe in mixing a poor cement with a better one to strike an average, as mechanical mixtures are never thorough. These samples should be taken from different parts of the bag or barrel, and not exposed to air or moisture until tested. Four or five pounds will be ample for one sample.

### 7. EXPERIMENTER.

Much practice is required before the student's tests are of any value, as the skill and exactness required can be obtained in no other way. It is important that the tests should be made in a room where the temperature can be kept uniform; otherwise the results will vary greatly. Briquettes made at a low temperature will take longer to harden and acquire a higher ultimate strength than those made at a higher temperature.

The samples should be tested as soon as possible after being taken from the original package; otherwise the results may be entirely different. For instance, the writer once rejected a carload of Portland because it set hard in five minutes. It also gave a very low tensile strength in twenty-four hours. A few weeks later he retested the same samples, about ten, which had been standing in paper bags in the laboratory, and found that the time of setting was then about one and a half hours, and the tensile test in twenty-four hours was much higher. This was an English brand, which had evidently been barrelled before being properly seasoned, and was air-slacked in the laboratory. The writer has had the same experience with other brands.

### 8. TESTS.

The samples should be tested for fineness, checking or cracking, and for tensile strength, both neat and with sand. *The Engineering News* advocates replacing the tensile tests by transverse tests. This is certainly worth looking into, but the writer has not had an opportunity lately to experiment in this line.

### 9. TEST FOR FINENESS.

Not more than eight per cent. should be retained on a No. 100 sieve (10,000 meshes to the square inch) made of wire, No. 40, Stubb's gauge, as recommended by the American Society of Civil Engineers. Coarse cement tested neat gives a higher tensile test than when more finely ground, but when tested with sand (as it always ought to be) gives much lower results. Thus an artificial stone made of cement and a small proportion of sand would probably be stronger than if made of neat cement. These requirements for fineness are those of the American Society of Civil Engineers, and would be important if the cement were only tested neat; but it is so well recognized that the finer the cement the higher the sand test that, as a rule, the cement is ground much finer than this specification calls for.

### 10. CHECKING OR CRACKING TEST FOR ROSENDALE.

At present the best test for free lime, etc., we have for Rosendale or natural cements is that suggested by the American Society of Civil Engineers, viz.: Make two cakes of neat cement, two or three inches in diameter, about one-half inch thick at centre, and with thin edges; place one in water as soon as set and keep the other in air. Observe from day to day. If the cakes are cracked at the edges, or distorted, or show blotches, the cement should be rejected as unsound. This test, however, may pass a poor cement, but will not reject a good one. For Portland cement the hot test should be substituted.

### 11. HOT TEST FOR PORTLAND.

All Portland should stand the following hot tests before being accepted: Make three pats or cakes, as before, of neat cement on a piece of glass, leave the first in damp air until set, the second for about six hours, and the third for twenty-four hours, after which place each in a steam bath of 200° Fahr. for three hours, and then in water of the same temperature for twenty-one hours each. If any of the pats show cracks, distortion, or swelling, the cement should be rejected, as it probably contains too much free lime or is underburned.

### 12. TENSILE TESTS—NEAT.

The cement, when made into neat briquettes with a section of one square inch in the neck, should stand the following tensile tests:

| Test. | Time in Air. | Time in Water. | Breaking strength in pounds per sq. in. | |
|---|---|---|---|---|
| | | | Natural or Rosendale. | Portland. |
| 1 day. | 1 hour, or till set. | 23 hours. | 40-80. | 100-150. |
| 1 week. | 1 day. | 6 days. | 60-100. | 250-550. |
| 1 month. | 1 day. | 27 days. | 100-150. | 350-700. |
| 1 year. | 1 day. | 1 year. | 300-400. | 450-850. |

In the case of a well-known and satisfactory brand, the cement may be accepted on the first and second tests, but the month and year tests should be made wherever possible, even if only for record. If the 1 day and 1 week tests give higher results than the above, the cement should be rejected unless the monthly and yearly tests are known to give correspondingly higher tests for that brand.

### 13. SAND TESTS.

The cement, when mixed with sand and made into briquettes as before, with a section of one square inch, should stand the following tensile tests :

| Test. | Time in Air. | Time in Water. | Breaking strength in pounds per sq. in. | |
|---|---|---|---|---|
| | | | Natural Cement. 1 Cement, 1 Sand. | Portland. 1 Cement, 3 Sand. |
| 1 week. | 1 day. | 6 days. | 30-60. | 80-125. |
| 1 month. | 1 day. | 27 days. | 50-80. | 100-200. |
| 1 year. | 1 day. | 1 year. | 200-300. | 200-350. |

As before, the cement will be accepted on the 1 week test, if the brand is known to conform to the other tests.

As a general rule, it is impossible to wait for a longer test than the 24 hours, or, at the outside, the 1 week test. For a strange brand these tests would be absolutely useless ; but if we know that a certain brand has been proved to stand all tests up to one year or more, and we have a sample, of which the short-time tests agree with the established tests of the brand, the assumption is that the long-time tests would also agree.

### 14. SECTION AND NUMBER OF BRIQUETTES.

The briquettes should break in the smallest section, which should be one square inch, and four or five briquettes should be made at one time.

### 15. PROPORTION OF WATER.

The amount of water required in mixing the cement will vary with every brand, and even with every lot of the same brand, and should be accurately determined in each case, for a very small difference in the proportion of water will greatly affect the short-time tests, and will also affect the long-time tests, but not to the same extent. A very slight excess of water will greatly decrease the tensile strength of the short tests, but eventually the cement may attain nearly as much strength as if mixed with less water.

The approximate amount of water required is as follows :

For neat Portland, 25 per cent. of the weight of cement.

For neat Rosendale, 30 per cent. of the weight of cement.

For 1 Rosendale to 1 of sand, 15 per cent. of the weight of cement and sand.

For 1 Portland to 3 of sand, 12 per cent. of the weight of cement and sand.

### 16. SAND.

For testing purposes a crushed quartz should be used of such fineness that it will all pass a No. 20 sieve (400 meshes per square inch, wire to be of No. 28, Stubb's gauge) and caught on a No. 30 sieve (900 meshes per square inch, wire No. 31, Stubb's gauge).

### 17. MIXING.

The proportion of cement and water should be accurately weighed, the cement placed in the form of a trough on a glass, or other impervious material, and all the water poured in at once, and rapidly but thoroughly worked, the mortar, which should be thick and plastic, being then pressed firmly into the moulds with a trowel without ramming. All working must cease before incipient setting commences.

### 18. MIXING SAND TESTS.

The sand and cement having been carefully weighed and thoroughly mixed dry should then have the water added as before.

### 19. REMOVING FROM MOULDS.

As soon as the briquettes are hard enough they should be removed from the moulds, and kept covered with a damp cloth until placed in water. This is especially important with Portland cement.

The moulds should be kept clean, slightly greased (using as little grease as possible), for if they are not properly greased the cement will stick to the moulds, and in case the grease is too thick it is liable to affect the strength of the cement.

### 20. SLOW SETTING.

Portland cement which is not to be used under the water (where a quick-setting cement is a necessity) should be slow setting, that is, take at least one hour to set hard.

As a general rule, a slow-setting cement will acquire a greater ultimate strength than a quick-setting cement of *the same brand.* Cement takes much longer to set when mixed with sand.

### 21. THE TESTING MACHINE.

The testing machine should be so arranged that the strain will be gradually applied at the rate of about 400 pounds per minute. Dropping water answers very well.

### 22. MOULDS AND CLIPS.

The moulds and clips should be of such shape that the briquettes will always break in the smallest section. The forms adopted by the Cornell University are the best that the writer has used.

### 23. HAND VS. MACHINE.

These results are all based on the assumption that the briquettes are made by hand and placed in the moulds by hand, the simplest method, and one which cannot be done away with entirely. Unfortunately, it is almost impossible to eliminate the "personal equation" and make all operators get the same results.

If good and economical machines for doing this work could be universally adopted much more uniformity could be obtained, and all of the above figures, etc., would be more or less modified.

### 24. TESTING EACH PACKAGE.

In a case where some of the samples taken from the same lot are satisfactory and some are not, whether as regards strength, setting, or cracking, the entire lot should be rejected unless the contractor agrees to pay for the cost of testing each bag or barrel. No mixing of good and bad cement should be allowed.

### 25. FREEZING CEMENT.

Cement mortar should not be laid in freezing weather, unless absolutely necessary. In the first place, the cement itself, especially if Rosendale, would be more or less injured by being frozen before or while setting. Again, the freezing and thawing of the mortar, even if it does not injure the cement individually, would probably crack or otherwise injure the masonry in which it was used. In this respect the laboratory test of a small briquette would be of very little use. Salt should not be used.

### 26. RE-SETTING.

No mortar should be allowed in the construction under any circumstances after it has once set.

The above requirements can easily be met by the cement dealers, but unfortunately the engineer often has to take a very strong stand to secure the cement he wants. He should send very clear and liberal specifications to the dealers, and then absolutely refuse what does not come up to them, and after a while he will be understood and have less trouble.

The writer once called for a slow-setting Portland, and he got a carload that set in ten minutes, and on the twenty-four-hour test broke at from 30 pounds to 40 pounds, which was at once rejected. His chief had instructed him to accept or reject on the twenty-four-hour test, but for his own satisfaction he continued the tests after rejecting, and found that samples taken and made at the same time as the twenty-four-hour tests in three months acquired a strength of 500 pounds, which was very good. Also, that samples which had remained in the laboratory for some time before being made into briquettes took over one hour to set, and broke at over 100 pounds in twenty-four hours.

In the meantime, however, another carload of the same brand had arrived, been tested and rejected, because half the samples set in ten minutes and half took much longer, and the contractor would not pay the expense of testing each barrel. The manager of the works where this cement was made explained that the agent had not informed him that a slow-setting cement was required, otherwise he would have sent it. He further added that he used two kinds of limestone—one for a slow and one for a quick-setting cement, and that when the time of setting was not specified he mixed the two together. Naturally, his mechanical mixture was not thorough.

The next carload, much to my regret, came from an entirely different place, and as it set hard in five minutes it was at once rejected. It should be explained that the writer had to give his instructions to the contractor, who, in ordering the cement, was probably careless about repeating his instructions, to his subsequent loss. After this, however, every carload was fully up to the mark.

This recalls a contractor who once wanted to use a very fine but clean sand, for the sake of economy, on the writer's work, and asked permission to do so. As the only objection to the sand was its extreme fineness, the contractor was informed that he could use it, provided he added sufficient cement to make the resulting mortar as strong as that obtained from using the coarse but dirtier sand as before. He declared that such was his intention, and ordered a number of loads. On the arrival of the first load, the writer took a sample to his testing room, and in due time informed the contractor that he would require about twice as much cement as before, which rather staggered him. He then declared that he did not agree to have the proportion of cement decided by a laboratory test, but by mixing a little in his hands. The writer informed him that he might as well enter a bet as regards the respective beauty of two girls, and after the bet had been fully arranged turn around and declare that the girls should only be viewed from the back. The contractor dropped the subject at once, and sold his sand to some one else.

# ASPHALT AND ASPHALT PAVING

By F. N. Speller, Grad. S.P.S.

Mr. President and Gentlemen,—This subject brings us into the province of roadway engineering, which has of late years grown to be one of the most important departments of our great profession, and therefore commends itself to the discussion of our Society.

Crude asphalt is closely related to the well-known compounds of hydrocarbons known as naphtha, petroleum, etc. It is regarded as the ultimate result of a series of changes, probably due to a chronic distillation of organic matter buried at great depth in the earth's stratified crust.

The operations which resulted finally in asphaltum produced the following compounds in order: (1) Naphtha; (2) Petroleum; (3) Mineral Tar; (4) Asphalt. These merge into one another with insensible demarcations, the heavier ones being produced from the lighter by evaporation and oxidation.

This is, necessarily, only a brief sketch; hence it will be impossible to go into scientific details as to the origin and chemistry of this interesting and useful mineral, except in so far as they come in in practice. I will therefore briefly mention the localities from which it is chiefly produced, and its treatment for paving.

## SOURCES OF COMMERCIAL SUPPLY.

Among the earliest records* which we have of the use of asphaltum is when the Egyptians, recognizing its good preservative qualities, used it in embalming their dead by saturating the linen in which the body was to be enclosed in liquid asphaltum, supposed to have come from the region around the Dead Sea, where it is to be seen to-day oozing up from the ground and saturating all local porous rocks.

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*Ancient history affords us numerous examples of the use of this material, chiefly as a cement, and its worth is well shown on examining these great structures after the ravages of 3,000 years, in many cases the cement being as good as when first laid.

The so called "European asphalt" is really a limestone impregnated with asphaltum. The chief supply is from Val de Travers, in Switzerland, and Seyssels, in France. It is of these bituminous limestones that the first European asphalt pavements were constructed in Paris in 1850.

A German rock asphalt gave 8.8 per cent., and a Sicilian b, limestone, used in paving, 11.5 per cent. bitumen.

American asphalt is derived from four principal sources :

(1) *Cuba.* This is of fair quality, and occurs in veins or fissures. Analysis : Bitumen, 70 per cent.; inorganic matter, 24.5 per cent.; water, 5.5 per cent.; total, 100 per cent.

(2) *California.* In the southern part of the state there occur extensive deposits, including all varieties of bitumen, from the light oils to malthas and hard asphaltum. A large and important deposit of bituminous sandstone also occurs there. The asphalt contains 80 per cent. of bitumen, together with other organic and mineral matter, and water.

(3) *Venezuela, South America,* produces Bermudez asphalt, which is by far the purest—in fact, so pure that it is difficult to transport, due to a shifting of the viscous cargo. Analysis (estimated on dry material): Bitumen, 94.97 per cent.; inorganic matter, 5.03 per cent.; total, 100 per cent.

It was only lately introduced, and has only been laid to a limited extent ; but its high degree of purity and other valuable properties, which will be pointed out later, should bring it successfully to the front.

(4) *Trinidad deposits,* and especially the *Pitch Lake.* These have supplied by far the largest per cent. of American asphalt.

The pitch lake is situated on the west side of the island of Trinidad, half way between its northern and southern promontories, near the village of La Brea. Geologically, the island is intimately related to the mainland. More than two-thirds of its area is of tertiary formations, and consists of loose sands, clays, limestone, etc., with deposits of pitch and lignite here and there.

The strata is highly disturbed and contorted, showing it to have been the seat of violent disorders at no very remote date. In fact, the island lies on the line of volcanic activity extending through the Windward Islands to South America, and although no sign of volcanic action is now found on Trinidad many vents are found on the other islands.

Back of La Brea the land rises quite rapidly until we reach the pitch lake, which appears to occupy the highest point in the locality, the ground falling in nearly every direction from it.

It has an area of 115 acres, is three-quarters of a mile from the sea, and is at an elevation of 138 feet above it.

In shape it is roughly circular, a half mile in diameter, and is nearly surrounded on all sides by a wall of palms and other tropical plants, forming a picturesque background.

The lake itself is not level, nor is it liquid, except in a few places near the centre. It appears to be made up of spherical or polygonal masses separated by star-shaped pools of water three to four yards wide at the top, and from four to twelve feet deep. From the nature of the pitch, if it were motionless, the entire annihilation of these pools would be only a question of a few days, for, although the pitch is almost as brittle as ice when struck, it will flow quite readily if given an opportunity. These areas are slightly convex, and vary from thirty to two hundred feet in diameter. The appearance of the lake, with these watercourses and dark masses, has been described by travellers as resembling marbled paper.

The above-mentioned masses owe the preservation of their form to a curious revolving motion in the pitch itself, by which the lower part in the centre is slowly rising *en masse*, displacing that which was originally there, and forcing it towards the circumference, where it is turned under, to reappear at some future date. The evidences of this motion are abundant. The surface is contorted into concentric wrinkles, the numerous gas cavities in the pitch are elongated into lines as they reach the surface, and the interior presents a laminated appearance. Another curious proof is found in the numerous sticks of wood which are involved in the pitch, and are seen obtruding inclined at all angles. On reaching the surface they generally assume an upright position, due to one end being retained in the pitch, and by the lifting of the middle. The cause of this motion has been ascribed to the expansion and contraction due to the great variation in temperature, which is sometimes as great as 100° F. in a day.

Although the pitch is as hard as gypsum, yet a person standing in one place would sink a few inches in a space of time, depending on his distance from the centre of the lake. Near the centre is an area of more or less liquid pitch occupying a few hundred square yards, although a report of 1837 places the area at three and a half acres. Much of this has, no doubt, undergone a change, making it like the remainder of the lake. The fluidity is in no wise due to high temperature, for the temperature of the soft spot is only about 95° F., which is the usual temperature of the locality.

At the soft spot the evolution of gas is apparent to the ordinary observer, but it, no doubt, occurs to a lesser extent all through the lake, causing the pitch to possess that peculiar appearance of Swiss cheese.

The land all down the slope to the sea, and on either side of the lake, is covered with pitch, which forms three miles of coast. It is generally covered by a foot or two of soil, and, except when very near the lake, is of a varied inferior quality. The land pitch has evidently been largely derived from the lake by overflows, but has subsequently undergone a change in its constitution. It occupies about 12,000 acres. As late as 1854 there has evidently been an overflow, as reports of that date describe numerous streams issuing from the circumference and extending down the slope, sometimes jostling one another in their course. These evidences are now covered with earth and grass, showing that there has been no overflow since. This is, no doubt, due to the large quantity of pitch removed during the last twenty years; in fact, by levels taken in 1892, compared with permanent bench marks established years ago, the surface has been shown to have sunk about one foot.

The supply is, from all appearances, not being replenished, and its extent is unknown, owing to the fact that an excavation fills up rapidly by the moving in of the sides and rising of the bottom.

The general appearance of the pitch from the lake is the same, except that from the soft spot. The great uniformity is well shown in the following results obtained by the United States Government chemist at Washington from a large number of samples collected from different parts of the lake:

| | Average. | Highest. | Lowest. |
|---|---|---|---|
| Water | 27.85 | 30.65 | 25.77 |
| Inorganic matter | 26.38 | | |
| Organic " (non-bituminous) | 7.63 | | |
| Bitumen | 38.14 | | |

Which when calculated for the dry substance becomes:

| | Average. | Highest. | Lowest. |
|---|---|---|---|
| Inorganic matter | 36.56 | 37.02 | 36.27 |
| Organic, not bitumen | 10.57 | 11.75 | 9.96 |
| Bitumen | 52.87 | 53.77 | 51.68 |

On the other hand, the land pitch varies greatly in composition with the locality, and does not exhibit that peculiar porous structure which the lake pitch possesses, except when found near the lake.

The commercial land pitch, which is carefully picked over and extracted near the lake, does not vary in composition perceptibly from the above lake pitch, but its actual difference is striking, even to a mere novice, and experience has shown that the average quality is unfit for paving. It therefore becomes important to distinguish between the land and the lake pitch commercially.

## DISTINCTION BETWEEN LAND AND LAKE PITCH.

As stated above, the difference is not revealed in an ordinary chemical analysis. It must therefore depend on some change in the character of the constituents; and as the non-bituminous organic matter and inorganic matter does not change, something must have affected the bitumen.

All the bitumen of the Trinidad pitch is soluble in $CS_2$, but only a portion is soluble in gasolene. The latter has been called by Boussingault *petrolene;* it is a sticky substance, and is the life of the asphalt, giving it its cementitious value. When extracted, it leaves a hard, cokey residue, containing the residuum of the bitumen called *asphaltene.*

The presence of a larger per cent. of petrolene causes lake pitch to possess a greater softness and utility than land pitch.

Owing to the difficulty of removing the water on the small scale without affecting the lighter oils, systematic investigation of the two asphalts has been carried on with the refined product.

Refining asphalt commercially consists in heating the crude material in an iron still to such a temperature as will evaporate the water without sensibly altering the light oils. The light organic matter rises to the top and is skimmed off, while some of the mineral matter will subside to the bottom. The product drawn off is refined asphalt, and renders the bitumen in a more available form for investigation and use. It is of great importance that the stills should be uniformly heated, and to this end the products of combustion are carried around them before going to the chimney.

I will here note a few of the principal tests employed to distinguish a poor asphalt from a good one, taking, for example, a few of the results obtained at the Toronto city engineer's laboratory last summer.

Different asphalts can be compared as to their relative usefulness as cements by estimating the amount of total bitumen which is petrolene in each.

For example, a Venezuelan sample, containing 97 per cent.* bitumen, of which 68.49 per cent. was soluble in naphtha, compared well with Trinidad lake asphalt. For, calculating in each case the per cent. of bitumen petrolene, we obtain figures in which the excess of inorganic matter in the Trinidad has no effect: Venezuelan, 70.5 per cent.; Trinidad, 70 per cent.

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*These figures were obtained by Clifford Richardson, U.S.Gov. Chemist for D.C.

The solubility seems to depend on the specific gravity of the naphtha largely, so that the same solvent should be used for comparative tests. In distinguishing between land and lake pitch from Trinidad, however, an analysis is seldom necessary, as the difference is sufficiently well brought out in certain physical tests, a few of the principal of which are given :

(*a*) *Softening* and *flowing* points. These are obtained by placing a small angular fragment of each sample on a bath of mercury contained in a small beaker. It is slowly heated by the small flame of a Bunsen burner placed underneath, the temperature being noted by a thermometer suspended in the mercury. At the softening point the particle will be seen to form a little black globule. On raising the temperature slightly, this will be seen to flatten out into a little disc. This is the point of flow indicated on the thermometer. The following are the extremes :

| | Soft. | Flow. |
|---|---|---|
| Refined lake asphalt........ | 180°-192° Fahr. | 189°-210° |
| Refined land asphalt ....... | 190°-237° | 210°-255° |

(*b*) *Per cent. of flow.* A piece of glass (5 x 8 in.) is taken with a scratch ruled across it near the top, behind which samples of the material to be tested are stuck, weighing about two grammes each.*

The glass is placed in an inclined position, at about 30° to the horizontal, in an air bath, heated uniformly to about 110°C., until the asphalt has flowed some distance, when it is removed, cooled, and the flow measured. Calling that of the standard 100, most refined lake asphalts range between 70 and 100, while a "land" will run as low as 28.

(*c*) The *specific gravity.* This affords a good test when Trinidad asphalts have been properly refined. Lake asphalt will usually fall below 1.39, and land always above it.

The following results, obtained from two asphalts being used in our own city, afford a good example of the utility of these tests :

| Series No., Refined Asphalt. | 10 | 11 |
|---|---|---|
| Bitumen ........................ | 53.32 p.c. | 56.20 p.c. |
| Inorganic matter ................. | 38.55 " | 36.77 " |
| Organic matter, not bitumen....... | 8.13 " | 8.80 " |
| Bitumen soluble in gasolene†...... | 28.90 " | 33.8 " |
| Per cent. of total bitumen soluble in gasolene ................. | 54.01 " | 60.14 " |

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*All these tests should be made at the same time on a standard sample kept for that purpose.

†Very light gasolene was used.

| Series No., Refined Asphalt. | 10 | 11 |
|---|---|---|
| Specific gravity | 1.4428 | 1.4010 |
| Softens | 230° Fahr. | 188° Fahr. |
| Flows | 275° " | 200° " |
| Per cent. of flow | 38.6 p.c. | 85 p.c. |

### PREPARATION OF ASPHALT FOR PAVING.

The question of road surfacing has been threshed out with characteristic thoroughness by the engineers of the great cities of the old world. In London, Berlin, and Paris, the asphalt surface has been received as a welcome substitute for stone and block pavements, and it has the reputation from eminent engineers of being the best general surface for city streets.

In Paris the first asphalt roadway was laid about 1850. About 1880 it fell into disrepute, through mismanagement in laying, and wood paving, for a time, was encouraged. However, in London and Berlin asphalt continued to grow in popularity, until to-day it is found on the majority of the principal streets in the above cities.

Léon Malo, the foremost of French experts on asphalt, pointed out to the Society of Engineers of Paris, in 1886, the causes of the above-mentioned temporary failure of asphalt there, and also, on account of the great quantity of wood paving which was being contemplated, the place which wood should occupy along with asphalt in the city paving, viz., that wood should, if used at all, be confined to the broad boulevards, while asphalt should be always used on the narrower streets and lanes.

It would be hard for an American to understand the progress which wood has made in Europe as a paver, in view of the disastrous experiments some of our large cities have made with it, without knowing something of the construction of these pavements in Europe. In the first place, only the *best* selected wood is used—usually white pine, cut into blocks six inches deep. They are often impregnated with a preservative, and are always laid on a foundation of concrete eight inches deep. The cost in Paris is about $3.75 per square yard, and 40 cents per square yard per year for maintenance. It is evident that few of our municipalities could stand such a luxury.

European asphalt pavements differ essentially from the American in being constructed of bituminous limestone, which has already been described. The one essential condition for any satisfactory street surface is a good foundation, and none is better than concrete.

Its advantages over others are threefold :

(1) It excludes moisture entirely.
(2) It is unyielding—perfectly solid.
(3) It facilitates resurfacing.

In Europe not less than eight inches is thought sufficient. The sub-grade is prepared so as to conform with the finished surface ; then the foundation is laid, and, when thoroughly dry, is ready for the surface mixture.

The latter is prepared as follows : The bituminous limestone is first ground fine, and heated in revolving cylinders to about 300° F. It is then spread over the foundation to the requisite depth, and stamped down to about two to two and a half inches in thickness. It will not stand rolling, as it runs into hills and hollows.

It is much more slippery than the American pavement, as it contains no gritty sand in most cases, but the latter is now being mixed with it to some extent.

The principle of all good surfaces should be to provide a durable, healthy, soft, and reasonably smooth cushion between this hard foundation of concrete and the wheels of the vehicles.

The first American asphalt pavement was laid in 1870 in Newark, N.J., by E. J. DeSmedt, the inventor of it.

It was constituted essentially the same as our asphalt pavements of to-day, viz., an artificial sandstone in which the grains of sand are cemented together with asphaltic cement.

Refined asphalt itself is too hard to make a desirable binding material, so it is tempered with residuum oil from the distillation of petroleum, for the lack of a better substitute. The adaptability of asphalt as the basis of this cement is unquestionable, as it (when good) combines the properties of elasticity and strength to a high degree. To demonstrate this fact, I have made a few experiments on the tensile strength of a few of these substances, and quote a few figures from the same below :

| | | |
|---|---|---|
| Refined "lake" asphalt, | 525 lbs. per sq. in. | Temperature about 60° Fah. |
| Refined "land" asphalt, | 330 " " " | |
| Asphaltic cement (lake), | 370 lbs. per sq. in. | Temperature 57° Fah. |
| " " (land), | 300 " " " | |

The above figures are averages of a large number of tests.

Various attempts have been made to substitute artificial material, as coal tar, for asphalt, but one only needs to see such a sample of this as the city of Washington possesses, when in the hot summer days the horses have to struggle through it, carrying away a portion of the surface on the tires of the wheels, to be impressed with its uselessness.

I will now speak briefly of the construction of this pavement in our own city. The surface mixture, when ready for laying, consists of asphaltic cement, 10-15 per cent.; sand and stone dust, 85-70 per cent.; carbonate of lime, 5-15 per cent.

Generally a sand is found which contains the requisite amount of lime.

The refined asphalt is melted in large rectangular wrought-iron tanks, the temperature being kept at about 325° F.

The residuum oil is pumped in hot, and the whole is agitated by air forced through wrought-iron pipes, sunk into the liquid mixture.

Owing to the considerable difference in specific gravity between asphalt and the oil, and because the former is insoluble in the latter, a great deal of agitation is required—about ten hours. The consistency of the cement should be tested from time to time by a penetration machine, and should run about 80°.

The quality of the oil is of next importance to that of the asphalt itself. The most particular requirements are that (1) it shall not flash below 325° F.; (2) it should not lose more than 4 per cent. when distilled at 400° F. for seven hours; (3) it must not contain cokey granular particles or hard scaly paraffine.

### PREPARATION OF THE FOUNDATION.

Before the pavement is started, all drains, pipes, underground wires, etc., which are necessary, are attended to, the proper parties being notified.

The sub-grade is carefully prepared, levelled, and rolled, if found necessary, for solidification. The kerbs are placed in position, either being set in concrete or gravel. The subsoil is drained by four-inch tile drains running parallel with the kerb in three rows, one under each kerb, and one under the devil's strip, or centre of the roadway, the former making connections with the catch-water basins.

If electric car tracks are to be laid, the sub-grade must be excavated to twelve inches extra in the track allowance, this being then filled in with six inches of ballast and compacted.

Girder rails six and one-half inches deep, weighing seventy pounds to the yard, are now universally used for electric railroads, and they require a very carefully prepared roadbed, owing to the great weight of the motors and the way in which it is concentrated.

The rails are laid on cedar ties, twelve by six inches, by seven feet long, perfectly sound. The grade is indicated by stakes every fifty feet, and the centre line of one of the tracks is run in carefully by the transitman.

Proper gratings to catch surface water are placed between the rails at intervals, and are directly connected with the sewer.

The roadway is now ready for the concrete foundation, which should be six inches deep.

The laying of the concrete must be done systematically, and as quickly as possible. The mixing is done on a movable square platform the width of the track allowance (16 feet).

The proportions are one part of cement (Portland) to three of sand, and sufficient broken stone—about eight parts—to give excess of mortar when rammed.

Mixing :—One-half the quantity of sand is spread upon the platform and one-half the cement spread over it, then the remainder of the sand, and, finally, the remainder of the cement. The whole is now thoroughly mixed in the dry state. Water is then added by a fine sprinkler, and thoroughly mixed with the sand and cement. The broken stone is now dumped on and the whole mixture turned over once or twice, and quickly shovelled on to the roadbed and carefully rammed by wooden rammers. The finished surface must show excess of mortar, and conform strictly to the line of grade. It is necessary to note a few points essential to the life of concrete : (1) The Portland cement should be repeatedly tested, and for this purpose a laboratory is necessary. (2) The sand should be clean and sharp, and may contain some gravel. (3) The broken stone should be of approved quality, and be broken to pass through a two-inch ring. (4) The most skilful workmen should be employed.

We are now ready to lay our asphalt.

The sand and lime are heated in revolving cylinders of sheet iron, and raised by belt elevators to the mixing floor, on which are situated the "cement tanks" and mixing machinery.

The machine in which the mixture is made consists of a cast-iron trough with a trap bottom. Running through the trough are two parallel shafts to which are attached blades, which, when the shafts revolve, work in and out between one another, causing the most perfect mixture. The hot sand and limestone are dumped in from carriages suspended from a track overhead. After a slight agitation, the asphaltic cement is poured in and the whole agitated for about one minute. By pulling a lever the bottom swings open, and the thoroughly mixed contents fall into a cart placed below, in which it is conveyed hot to the roadway. It is rare, even in twenty to thirty analyses of this mixture, taken from any one street, to find a variation of more than 1 per cent. in the bitumen present.

The mixture must arrive on the street at a temperature of not less than 250° F., and is quickly spread out, raked even, and rolled, first with light rollers, then with the heavy seven to ten-ton steam rollers, until no further impression can be made on it. When nearly finished, Portland cement is swept over the surface dry, and later receives its finishing roll. It is usual to lay the pavement in two layers, first, the cushion coat, one-half inch thick, and then the surface mixture proper, two inches thick.

Too much importance cannot be placed on the experience of the workmen, as every detail requires skill and care of a very high degree.

## ADVANTAGES OF SHEET ASPHALT COMPARED WITH OTHER PAVEMENTS.

The properties which an ideal city pavement should possess are well known, but, owing to the variety of local conditions, it is not always easy to compare, in a general way, one pavement with another. I will therefore briefly endeavor to show the advantages which this pavement possesses for a city such as our own.

The different systems will be placed in order of merit under each head.

1. *Durability.* (*a*) Granite setts for very heavy traffic. (*b*) A good asphalt surface is equally durable for moderate traffic; in fact, the more traffic it gets, up to a certain limit, the better. Some asphalt pavements show signs of disintegration for want of traffic. (*c*) Brick. Results are, however, uncertain; and owing to the variation in quality, it is risky to subject it to heavy traffic as a rule. (*d*) Wood.

2. *Healthfulness.* Including noiselessness and cleanliness.

*Noiselessness.* (*a*) Asphalt produces a minimum of noise, which is much less noticeable in summer, when the pavement is softer than in winter. (*b*) Wood pavement, when new, is about equal to asphalt in this particular, but, when worn, falls decidedly to second place. (*c*) Brick. (*d*) Granite setts.

*Cleanliness.* (*a*) Asphalt. Its merit here is unquestionable, as there are no cracks to retain putrefying matter; the nature of the surface facilitates cleaning and removal of surface water, and the surface is absolutely impermeable. (*b*) Brick. (*c*) Stone. (*d*) Wood. The latter two are probably at par except when the wood is new, when it might be placed first.

3. *Traction and safety.* I here quote the results of a series of tests made to determine the resistance to traction on roads:* "If one horse can just draw a load on a level road on iron rails, it will take one and two-thirds horses to draw it on asphalt, three and one-third on the best Belgian block pavement, five on the ordinary Belgian pavement, seven on good cobblestones, thirteen on bad cobblestones, twenty on an ordinary earth road, and forty on a sandy road." But there is evidently a limit to the ease of traction caused by, with most materials, increased slipperiness. This brings us to what many consider the great weakness in asphalt. The various forms of block pavement certainly have an advantage in having cracks in which the horses may gain a foothold, but the surface of these blocks invariably wears very smooth, while asphalt wears down naturally with a gritty surface. Under certain conditions, *when the asphalt is kept wet by a fine sleety rain*, it is slippery as is everything else, but it is dry in a couple of hours after the heaviest storm, while most other pavements, under the same conditions, retain the evidence of it in the form of mud and water for as many days.

4. *Popularity.* This must ever be one of the most vital influences in the existence of any system of paving, as well as that of a good many other engineering and architectural constructions.

There are at present in the United States and Canada fifty of the largest cities in which asphalt has been adopted, in some cases almost to the total exclusion of other systems, as at Washington.

Between 1880-1890 there was laid in the United States 6,803,054 square yards of asphalt, representing 446 miles 26 feet wide, and since then it has received a great impetus.

The asphalt laid in Europe during the above decade was about one-fourth of that laid with Trinidad asphalt in the United States.

5. *Cost.*† Including first cost and maintenance.

This varies, of course, with the locality. In Toronto the order of cheapness is: (*a*) Wood, (*b*) asphalt and brick‡ (about equal), (*c*) stone setts.

*Maintenance.* The contractors are required to keep the pavement in order for five years, and some experts say that if an asphalt pavement is going to go to pieces during its natural life it will manifest this during the first six months of the same.

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*By Rudolf Herring, C.E., Philadelphia.

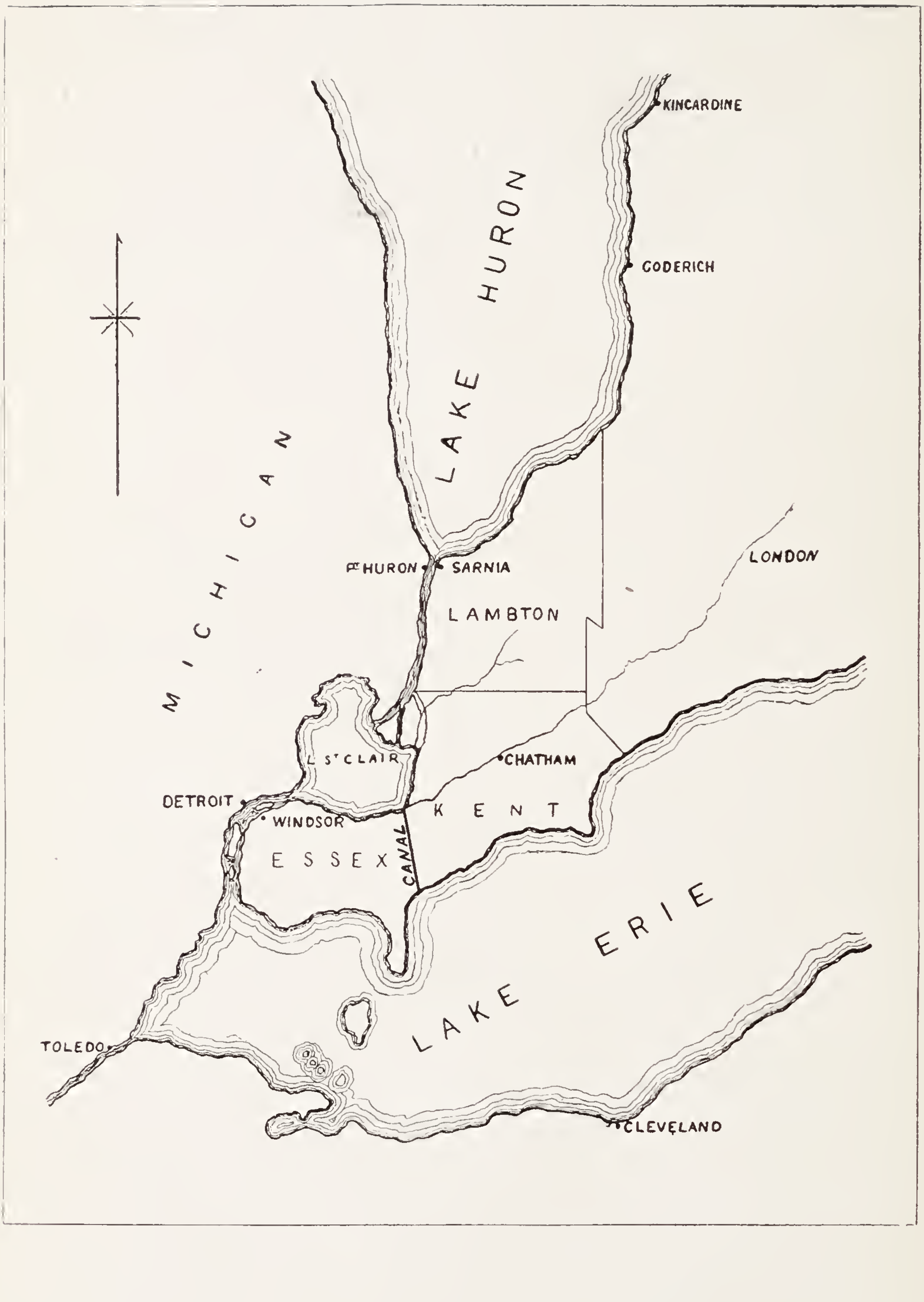
†The costs of these systems of paving in Toronto in 1893 were:
(*a*) Wood (cedar, six inches in depth), on sand, per square yard 70 cents.
" on concrete (six inches), $1.60 per square yard.
(*b*) Asphalt (two and a half inches), on concrete (six inches), $2.60 per square yard.
(*c*) Brick, single course on six inches of concrete, $2.50 per square yard.
(*d*) Granite setts, on six inches of concrete, $3.80 per square yard.

‡So far, we have had to import our brick, and the first cost of the material is doubled by duty and freight.

It is evidently impossible for one pavement to embody all the good properties of an ideal pavement, but our object should be, under the existing conditions, to choose that system which will approach it most closely.

In many cases, undoubtedly, asphalt may be replaced with advantage by some other system ; but for all general requirements in our large cities it approaches the ideal, if not perfectly, at least as well as any which has so far been brought forward.

Toronto, January 17th, 1894.


KINCARDINE
LAKE HURON
GODERICH
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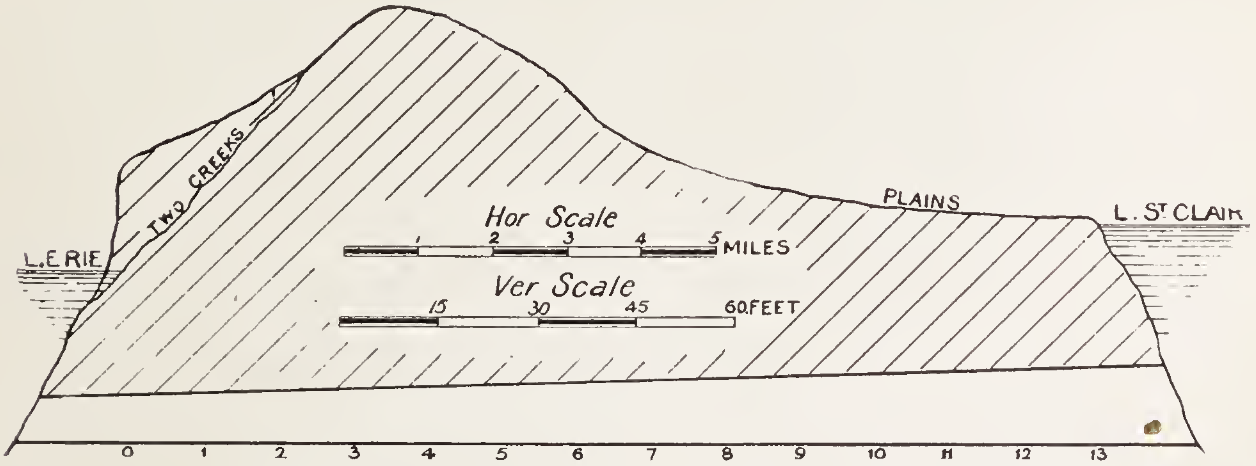
SARNIA
LONDON
LAMBTON
L. St CLAIR
CHATHAM
DETROIT
WINDSOR
KENT
ESSEX
CANAL
LAKE ERIE
TOLEDO
CLEVELAND

# PROPOSED ST. CLAIR AND ERIE CANAL

J. C. Macnabb, O.L.S.

The present St. Clair and Erie Canal scheme is the revival of an old project that was talked of fifty years ago by the early settlers who were seeking some means of relief in the matter of drainage, and it has been before the public more or less prominently at intervals ever since, though the requirements of the times have changed the character of the proposed work, and now a canal is contemplated instead of a drain.

Three surveys have been made by different engineers at different dates with practically the same results, which show a difference of level between the surface of Lake St. Clair and that of Lake Erie of five feet ten inches. As is shown in the accompanying plan and profile, the route of the canal would be about from the mouth of the Baptiste Creek southerly, taking advantage of the low levels of Baptiste, Trembly, and Two Creeks to the mouth of Two Creeks on Lake Erie, and this line gives almost a straight run between Lakes Huron and Erie, effecting a saving of sixty miles, as compared with the line at present travelled.



The physical characteristics of the route do not involve any engineering difficulties, as the thirteen and one-half miles of cutting consists of clay and clay loam, with possibly some sand in the neighborhood of the summit. The deepest cut necessary to give eighteen feet of water would be about forty-five feet, or an average cut of about twenty-two feet throughout.

At the St. Clair terminal there are large tracts of fen lands extending three and four miles inland from the shore of the lake; it is expected that these lands will be brought into cultivation by being drained by the canal. At the southerly terminal on Lake Erie, the estuary of Two Creeks presents an almost land-locked harbor of sufficient area to accommodate all the shipping that would meet at that point.

The development of the lake traffic of late years has been receiving greater attention from carriers and engineers than was usually devoted to it, as the annual rate of increase has been enormous. During the year 1890 twenty-two million tons passed between Lakes Erie and Huron, and during the year 1891 the tonnage passing through Detroit River exceeded by ten million tons the tonnage of the two ports of Liverpool and London. This is probably due to the opening up of the north and west and increased carrying facilities presented by the new type of freighter, named the *Whaleback*, by which a ton mile can be made by the expenditure of 1.8 pounds of power at a cost of 0.0018 cents, which compared with the power and cost to make a ton mile on an average railway, viz., 9 pounds and 0.009 cents, leaves a very large balance to the credit of the waterway as a means of transportation. Canada possesses a natural highway to the seaboard of over two thousand miles in length, with but seventy-two miles of detention by lockage; whereas the United States route from Duluth or Port Arthur *via* the Erie Canal to tide water has 352 miles of constant detention by lockage. As a writer on the "other side" aptly puts it: "Canada retains the key of the carrying trade of the great lakes to the ocean, not only from her own, but from American, shores. From Duluth as much as from Port Arthur, from Chicago as much as from Toronto, the way to the Atlantic for wheat and minerals is by the St. Lawrence. It will form a great bee line for the commerce of two hemispheres which, by reason of its few obstructions and detentions, its freedom from the necessity of breaking bulk, and its minimum cost of transportation, is destined to control a business which no imagination of man can picture or estimate." Whilst lessening the distance materially, the proposed work would also avoid the dangerous navigation met with at Grosse Point, Bar Point, Limekiln Crossing, Colchester Reef, and Point Pelée. The company now applying for a charter from the Dominion House is composed of American capitalists in Duluth, Buffalo, and New York, and their representatives on the grounds state that they will make the canal eighty feet bottom width, with eighteen feet of water; and give, as a rough estimate of the work, between four and five millions of dollars. This is roughly approximate, as no location surveys have been made by them.

The canal would be a great improvement on the present route and to the territory through which it would pass, so that it is to be hoped that the present company may not prove a bubble like its predecessors.

# MOUNT BROWN AND THE SOURCES OF THE ATHABASCA.

By Prof. A. P. Coleman, M.A., Ph.D.

If the camel be the "ship of the desert," the cayuse pony is the "canoe of the mountains." To the inexperienced rider he is as cranky and tottish as any birch bark in a rapid, but with certain virtues as well as vices.

Our nine ponies were awaiting us at my brother's ranch in Morley on the 8th of last July (1893), and all that remained to do was to capture them and endow them with their loads. Some had not come under the hands of man since the summer before, and to lasso, saddle, and pack them required the efforts of all four of us, as well as the hired man on the ranch. One of them, the pinto, was hunted in the large field for more than an hour by three men on horseback before being coralled and caught. Soon after noon, however, all was ready, and we commenced our three-hundred-mile journey through the mountains to Mount Brown.

Our outfit was the usual one for the mountains, except for a canvas boat, the "Athabasca," most inconvenient to pack, but, as we soon found, quite indispensable in crossing rivers.

The party consisted of Mr. Stewart, Mr. L. Q. Coleman, and myself, with Frank Sibbald as cook and packer. Last summer's experience had shown that Indians, though picturesque additions to a party, are more trouble than they are worth when once beyond their own hunting grounds; so we set off without guides, and found no reason to regret their absence.

As far as the Kootenay plains, on the Saskatchewan, our route was the same as in our former expedition, following the well-travelled Stony trail through the foothills to the Red Deer, then into the mountains, over a pass to the Clearwater, over another pass to White Rabbit Creek, which we followed down to the Saskatchewan.

Chief Jonas, with his family and one of his braves, kept pace with us day by day, and not long after we camped every evening we saw a white cone, with a smoke-browned top, rise among the trees a few hundred yards off. Then the chief and his young man would come nonchalantly into our camp, following the odor of frying bacon, and sup with us. The chief was dressed in shabby white man's clothes, but with moccasins to show his race, and black ostrich plumes in his felt hat to show his rank. The young man wore the usual blanket costume, with fringed leggings, which parted company with his upper garments when he squatted on the ground, leaving a broad expanse of bronze thigh for the pestilent mosquitoes to pasture on.

The chief is a sinewy, graceful, dignified man, rather under medium height, speaking in a suave, well-modulated tone, with agreeable gestures. Sibbald was brought up with the Stonies, and is one of the few whites who understands their guttural language, so that he got a good deal of useful information for us from Jonas. One evening the chief borrowed a pencil and piece of paper from me, and next morning brought a map of the rivers, lakes, and trails of the region as far to the northwest as he was acquainted with it. This proved of value at least once in our journey.

The women and children we saw only on the march. The chief and his man rode gaily ahead with their guns, while a lithe, well-built girl of eighteen looked after the pack animals, riding astride her pony as erect as a guardsman.

Owing to the unusually heavy snowfall of the previous winter, and the sunny weather of the summer of 1893, the rivers were much higher than usual, and, as Chief Jonas and other Indians foretold, the Saskatchewan was unfordable. At the usual ford its strong, muddy current would have swept away horse and man. Jimmy Jacob, last year's guide, who was hunting sheep in the neighborhood, had promised to show us a ford for $5, but, deeming discretion the better part of valor, did not arrive at the time agreed upon to earn his money.

Without waiting for Jimmy, we proceeded a few miles down the river to a point where it flows in a single channel, and, unrolling the "Athabasca," ferried across, first driving the horses in and making them swim over.

To our astonishment, we found, camped near the ferry, a blue-eyed, stubble-bearded prospector, named McGavan. He was alone, except for a bright little spaniel and three ponies, and had met no one since leaving Laggan a month before. He was sawing boards to build a boat when we arrived, but was happy to secure a passage in the "Athabasca" next morning. It was midnight before we finished ferrying and got our camp made; and the first thing we heard in the morning was McGavan's cheerful whistle and the jangling of his cow-bell, as he sat by his bundles and his ponies on the mud of the bank, waiting for the ferry. He informed us that he was on his way to the most northerly tributaries of the Saskatchewan, in search of the quartz reefs which he believed to supply the gold of the placer mines near Edmonton. During the past few seasons he had prospected every stream entering the Saskatchewan from the mountains except the ones he was now going to; and since he had found no gold in any of the others, he was convinced, in spite of the geological survey, that these most remote tributaries must hold the treasure. It was too bad to see so much energy and courage spent in a perfectly hopeless quest.

After crossing the river our ways parted, McGavan leading his ponies eastward, and we turning westward to the Hahasigiwapta, or Cataract River, as it may be translated, one of the larger tributaries of the Saskatchewan. We followed the valley of the Cataract River westward, from the foot of Sentinel Mountain to its source, a distance of about fifty miles. It is a very rapid, blue-green river, heading, 1,500 feet above its mouth, among striking mountain peaks, in a charming lake, clear, cold, and trout-haunted, fed by a magnificent spring forty feet wide. We ascended a tableland, which rises to about 7,000 feet beyond the lake, and, after a tramp of eight miles to the southwest, looked down upon the Saskatchewan, already a respectable river, though within thirty miles of its source.

Turning to the north, we crossed a divide, which we named Cataract Pass, at 7,550 feet above the sea, and made our way down the Brazeau. The pass is not a very easy one, since snowslides have mowed down the forest for half a mile in width at one place, leaving an almost inextricable tangle of fallen trunks; and at the summit we found so much snow on July 24th that we had to make a wide detour up the mountain side to get safe footing for our horses. Several glaciers come down to the level of the pass, feeding an indigo-colored lake amidst the snows of the summit. Peaks of a very bold and rugged type rise close at hand; and at the highest point no trees can be seen, nor scarcely any other green thing, so that the whole effect is wild and severe.

A sharp descent of 1,200 feet leads to the headwaters of the Brazeau, where we camped for a few days to explore the neighborhood, and, particularly, to find a pass over to the Sunwapta, which Chief Jonas had marked on his map. The mountains here are of the inclined plane type. We climbed one which rises 9,600 feet above sea level, and another rising to 10,150. The latter, which faces the head of the valley, gives an admirable view down the Brazeau, as well as over the upper Saskatchewan, with its splendid mountain surroundings. To the northwest, we could see the blue valley of the Sunwapta and its far-off junction with the Athabasca, the limit of our journey last year.

The pass mapped for us by Jonas enabled us to avoid a long detour by Brazeau Lake and Poboktan Creek, the route we had followed the summer before. The trail climbs quickly up from the Brazeau into a narrow desolate side valley, treeless for seven or eight miles, and, when we crossed it, clammy with half-melted snow from a storm the night before. The descent towards the Sunwapta led over muskegs, past beaver ponds, and through horrible burnt woods where the soil had been consumed, leaving sharp stones that rolled under the feet of the horses on the steep side of the gorge. Two beasts rolled over, load and all, till they reached the creek below. We named the pass, which reaches 7,700 feet, and the creek which flows into the Sunwapta, in honor of the chief, Jonas' Pass and Jonas' Creek.

To explore the upper part of the Sunwapta valley, we rode seven miles up the river through dreary burnt woods, and climbed a mountain, stopping at 10,000 feet, several hundred feet beneath the highest summit. A wonderful view spread before us. Five thousand feet below lay the river branching into a hundred narrow, interlacing channels, looking from our perch like a ravelled skein of silk flung upon the ground. This spreading into numberless channels is a common feature of glacial streams near their headwaters. The mass of fine "rock flour" and pebbles with which the glacier burdens them is dropped at the first level reach of their bed, and the stream is perpetually seeking new channels through the loose materials it has deposited in its own path.

To the south of us near the head of the valley rose sharp and steep mountain points, and across the valley there was a huge dome-shaped mass of snow brooded over by heavy clouds, and sending long glacier tongues between black precipices into the valley. We probably saw the same dome-shaped mass over which the clouds hovered from a mountain top thirty or forty miles farther away the previous summer.

We estimated that the higher points in the group rose some thousands of feet above us, probably to 13,000 feet, but not more than 14,000 feet above sea level. So far as we have observed, these are the highest mountains in Canada. As the river is here about 5,000 feet above the sea, and the mountains rise abruptly 7,000 or 8,000 feet higher, the effect is very impressive.

Turning down the river from our camp at the mouth of Jonas' Creek, we were presently stopped by a rock slide impassable for horses. A huge slice of quartzite and conglomerate, a mile wide and hundreds of feet thick, must have loosened itself high up near the crest of the mountain and slid down into the valley, burying square miles of its surface with gigantic blocks of stone, damming the river, which now rushes over the obstruction in a series of rapids, and hurling great masses half a mile up the opposite slope. The yellowish scar from which the avalanche slipped can be seen distinctly on the mountain, so that the event took place probably not more than a century or two ago. What a tremendous sight it would have been from the opposite mountain !

Fording the river, we circumvented the rock-slide and made our way, often by dint of much chopping on tree-encumbered trails, past the falls of the Sunwapta, past its junction with the Athabasca, to the falls of the latter river, where we camped within sound of its thunder. The Athabasca falls, though only about sixty or seventy feet deep, are very striking. The river here, nearly a hundred yards wide, and too deep and swift to ford, gathers itself together, swerves suddenly to the left and plunges as a chalky green flood into a black chaldron, out of which steams a rainbow-haunted spray cloud. The canon into which the river disappears sweeps a semi-circular curve, and its walls close in so much at one point that some daring man, years ago, flung six small spruces across it to make a bridge. It would need a cool head to cross them now, half decayed from the dampness of the spray.

Our way down the river grew still more difficult after this, and the axes had to be in constant use. It is evident that no one has used the trail for some years. One very hard day's work advanced us only three or four miles. We came out at last upon a well blazed and beaten trail through the widened valley, with here and there stretches of prairie, delightful to behold after weeks of battling with burnt forest. One evening the half bark, half laugh of coyotes came to our ears, rejoicing the heart of Frank, who is a true plainsman. "It's a decent country where there are coyotes," said he, and looked more cheerful than for a long time before. To camp on a meadow of soft green grass beside a brook shaded with densely growing willows, where everything is clean and peaceful, has indeed a wonderful charm after days of burnt woods, where all day long you have been smeared and smudged by charred branches and tree trunks, until everything about man and horse is foul and sooty before the evening camp is pitched between shadeless black trees on a soil of ashes and sand. We began to think we were getting into "God's country" again, to use a westernism.

We had now reached nearly the latitude of the mouth of Whirlpool River, according to Mr. Stewart's observations, but no marked valley opened up on the other side of the Athabasca, and we were in doubt where the river entered. As it happened, we passed through a bit of woods cutting off a bend of the Athabasca at the critical point, missed Whirlpool River, and passed on to the Miette, a few miles farther down. This we took for Whirlpool River; and it was a day or two before the difference of latitude, the wrong direction of the valley, and the finding of railway survey pegs, convinced us that we had entered the Yellowhead Pass (Tete Jaune), where a survey was made a number of years ago for the Canadian Pacific Railway.

On the maps, Henry House, a trading post, is placed opposite the mouth of the Miette, but we found no trace of any house in that position. It has, perhaps, been destroyed by fire, and the site covered with second-growth trees. The law of the map-maker seems to be that of the consistent Calvinist, "Once in grace always in grace." A name once installed on a map, whether rightly or wrongly, stays there forever. We found that the Yellow Head Pass is still in use. A party had gone over it a week or so before us with horses much larger than our little cayuses, to judge by their big hoof-prints.

We ferried back across the Athabasca, and retraced our steps for a few miles, anxiously looking out for the mouth of Whirlpool River. Our first hint of its presence was given by the clearer green of the water on the opposite side of the Athabasca, which may be noticed a mile or two below the entrance of the Whirlpool.

At the mouth of the Miette, according to the railway survey, the Athabasca is 3,329 feet above the sea, but its descent is rapid, and we found the mouth of Whirlpool River about 300 feet higher.

We ferried across the Athabasca once more, and followed up the impetuous, sea-green Whirlpool River to its source. It is fordable with difficulty in its lower reaches, and my brother, on the tallest horse of the outfit, had to swim in exploring for a ford.

The Athabasca Pass was a thoroughfare for the Hudson Bay Company more than half a century ago, their voyageurs crossing it summer and winter; and it was used by hundreds of ponies and dog teams during the explorations for the Canadian Pacific Railway about eighteen years ago, so that we expected to find a good trail. In this we were disappointed. The pass has apparently not been used for a number of years; portions of the trail have been undermined and swept away by the river, and other portions were so tree-encumbered that we had a great deal of chopping to do.

The scenery along the way is often fine. A glacier, comparable to that of the Rhone, sends its blue ice-front down almost to the level of the valley at one point, and supplies a third of the water of the river. Still higher up the pass other large glaciers provide the rest of the flood, until, as one approaches the watershed, the Whirlpool dwindles into an insignificant rivulet rising in a pretty little tarn at the head of the pass. This pond is the Committee's Punch Bowl, which masquerades on the maps as a lake eight or ten miles long, sending a river southward as well as northward. By careful searching, we found a rill trickling between the stones at the other end of the Bowl and flowing south—a tributary of the Columbia—so that this little pool divides its snow-fed waters between the Arctic and Pacific Oceans.

The Punch Bowl is about 150 by 100 yards in dimensions, sufficient, one may be permitted to suppose, to brew punch for a large committee, even of well-seasoned Scotchmen such as one finds in the employ of the Hudson Bay Company.

Moberly puts the elevation of the Punch Bowl at 6,025 feet, but we found its height to be only 5,710 feet above sea level.

If the Punch Bowl was a disappointment, Mount Brown, which we had come so far to see, was much more so. Keith Johnson refers to it as 15,990 feet high,* and Reclus as 4,875 metres, or 15,980 feet high.†

The botanist Douglas, who went through the pass in 1826, has the credit of naming Mounts Brown and Hooker for the two great English botanists. Whether he gave them the heights we are accustomed to see in works on geography I do not know, not having been able to obtain copies of his papers on that part of his travels.

On the maps Mount Brown stands a little northwest of the Punch Bowl, but the only mountain answering to this position in nature is not particularly striking as seen from the valley. We passed several far handsomer and loftier peaks on our way up, so that we were deeply disappointed. Owing to a severe accident to my knee, I was unable to walk more than a few hundred yards when we camped at the summit of the pass; but when I surveyed the mountain, which I had toiled so long to see, it no longer seemed so great a privation not to join in its ascent. Mr. Stewart and my brother, with Frank as companion most of the way, made the ascent on August 21st. They met with no very serious difficulty, except a mile of steep snow field, until just beneath the summit, where a cornice of snow proved unscalable. They estimated this cornice, which covers the crest of the mountain, at less than one hundred feet in thickness. Readings of the aneroid barometer and of the boiling point thermometer show the height at which they stopped to be 8,950 feet, giving about 9,050 feet as the full height of the mountain, which rises only 3,340 feet above the pass.

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*Physical Atlas of Natural Phænomena, p. 26.

†Nouvelle Géographie Universelle, p. 261.

There can be no mistake as to the mountain, for no higher point rises beyond it west or northwest of the Athabasca pass, so far as could be seen from the summit. Mount Brown must descend, therefore, from its undeserved reputation as the highest mountain between Mexico and Alaska. There are hundreds of peaks higher than it towards the east and south, though probably none reaching within 2,000 feet of its reputed height. If Mount St. Elias proves to be within Canadian territory, instead of being the corner stone of Alaska, as claimed by Americans, its altitude of nearly 18,000 feet puts it far in advance of any other Canadian peak, and it has no rival in North America, except Orizaba in Mexico, which; according to some accounts, is a few feet higher.

During our return journey we asked ourselves again and again how the height of Mount Brown could have been so enormously overestimated as 6,000 or 7,000 feet, and we have found no answer to the question. Scores, if not hundreds, of men, many of them well-trained engineers, have made the pass a thoroughfare on the business of the Hudson Bay Company, or of the railway surveys. How did they fail to slice off some of the undeserved thousands of feet?

I should mention here that Dr. George Dawson, in a private letter on the subject, expressed the opinion that Mount Brown would turn out to be not more than 12,000 feet high when climbed.

The case of Mount Hooker we found less easy to settle. Johnson makes it lower than Mount Brown, Reclus higher.* The point nearest in position to that on the map is only about 8,000 feet high, as determined by Mr. Stewart and my brother, but a handsome, glacier-covered mountain, just east of the Punch Bowl, probably reaches 11,000 feet, and there are summits a few miles southeast that perhaps surpass 12,000 feet. Unfortunately, lack of time prevented our climbers from ascending any of them.

The Punch Bowl suggested no ideas of conviviality when we visited it last summer, for we had not even a flask of brandy with which to celebrate the end of our journey. The little meadow of matted sedge, surrounded by stunted spruces on three sides, and by the limpid pond on the

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**Loc. cit.*, Johnson says 15,700; Reclus, 16,979 (5,180 metres).

other, was the type of the sober and restful. Whistlers, or marmots, inhabited every rock heap around, and piped warningly whenever a tree was cut for fuel, or any other unusual sound aroused them. In revenge for this surveillance two of them, pursy as aldermen in their handsome gray fur waistcoats, fell to Mr. Stewart's rifle, but, to our sorrow, proved as rank in the pot as even porcupine. Caribou left their large hoof-prints on the river flats not far away, but we failed to get sight of them.

One day, when only the packer and my crippled self were left in camp, a full-sized cinnamon bear strolled leisurely down to our meadow and stopped suddenly fifty yards from where we stood at the tent door, apparently catching the scent of our footprints where we had gone for wood. The crest of coarse hair rose on his shoulders, he looked round at us, and then strolled as leisurely as ever into the woods again, with a courteous air of not wishing to intrude on our privacy. Frank mounted his pony, and, taking the gun, rode after our friend, the bear, but the pony stopped short, trembling, when he scented the cinnamon, and could not be forced to go any farther.

The black bear is much more cowardly than the cinnamon or grizzly. Two which we came upon galloped off as fast as their clumsy legs could carry them, and one never stopped till he had swum the Athabasca.

Fortress Lake is only ten or twelve miles from Punch Bowl, and it had been our intention to strike across to it; but, finding no route possible for ponies, we turned back the way we came, following the Whirlpool River to its mouth, ferrying across the Athabasca, and retracing our steps up that river to the junction of the Sunwapta. This we forded near its mouth, and then made our way, with some chopping of trails, to Fortress Lake, travelling eighty or one hundred miles to advance a dozen. Most of the way from the mouth of the Sunwapta we followed the trail made by Job Beaver, who led seven lodges of Stonies to the lake several years ago, the only visitors, so far as we could discover, who had looked upon Fortress Lake before us.

Job Beaver was, perhaps, the most enterprising man among the Stonies, a sort of unlettered Stanley, who opened up many new trails in the mountains, chopping his way with an axe as keen as if wielded by a white man. We had followed his footsteps for many a mile, and had blessed him for his enterprise. Last winter his eldest son died of consumption, and Job was so much affected by the loss that he committed suicide. At least that is stated by the whites at Morley, though the Indians will admit only that "he was wrong in his head before he died."

In honor of this intrepid explorer, we named the western fork of the Athabasca, which is somewhat smaller than the main river, though more than fifty yards wide where we crossed it, and difficult to ford, Chaba River—Chaba being Stony for Beaver. The name is a memorial in another sense also. Many and immense beaver dams exist along this river, though the race seems now extinct, whether exterminated by Job and his comrades, or, as Chief Jonas avers, by some contagious disease.

Passing the poles of the seven teepees, we came out upon the shore of Fortress Lake, and feasted our eyes once more on its opaline blue-green waters, set in dark forests untouched by fire, and reflecting splendid ruddy cliffs and rock pinnacles, and the far-off whiteness of immense snow fields.

We had cherished a hope of launching our boat, the "Athabasca," on the waters of the Punch Bowl, until we found that pond too small to make it worth the trouble; but now we quickly had her afloat on the beautiful lake beside our camp. After hard pulling in crossing swift and dangerous rivers, it was a delightful contrast to float idly on the lake, or to row furiously after the half-fledged ducks, which seemed so little afraid of man.

One disappointment awaited us. After promising ourselves trout as a relief from the monotony of bacon, we trolled and still fished and set night lines, we displayed the charms of a silver spoon, of grasshoppers, of flies, and of pork rinds, and had never a bite as reward. The lake looks the very home of mountain trout, but is apparently void of fish.

We had discovered the summer before that Fortress Lake has a subterranean outlet into a small tributary of the Athabasca, and we now found that a canal, half a mile long and six feet deep, would drain it into that river. At the opposite end of the lake, which is eight miles long, we found a beautiful clear stream, nearly as large as the Miette, flowing west into a turbulent river coming from the north, undoubtedly Wood River, an important tributary of the Columbia. Thus Fortress Lake, like the Committee's Punch Bowl, sends its waters to the Pacific as well as the Arctic Ocean. As the Punch Bowl is represented on the maps about the size of Fortress Lake, one might almost suppose they had been confounded. Fortress Lake lies east and west, instead of north and south, however, and no trail leads past it down Wood River.

The lake stands 4,330 feet above the sea, so that the pass is nearly 1,400 feet lower than Athabasca Pass; 950 feet lower than the Kicking Horse Pass, followed by the Canadian Pacific Railway; and only 610 feet higher than the Yellow Head Pass.

We had intended to do some exploring and mountain climbing about Fortress Lake to complete last year's work, but smoke from some distant forest fire drifted over us, reducing the mountains, in a day or two after our arrival, to colorless ghosts, and destroying all chance of distant views.

After a few days of idleness, the only real holiday of our summer, we began a rush for home, leaving the lake on September 4th, following the Athabasca down to the mouth of the Sunwapta, ascending that river, crossing Jonas' Pass to the Brazeau, and following the Cataract Pass and River down to the foot of Sentinel Mountain on the Kootenay plains.

Here Mr. Stewart made a sudden resolve to run down the Saskatchewan in our canvas boat, and, failing to dissuade him, we divided to him one-fourth of all our sadly diminished goods and bade him farewell. Five minutes after he was out of sight beyond a bend, and had commenced his lonely journey, at first rushing through the rapids of the mountains, then sweeping more gently through the plains, till he reached the end of his voyage at Edmonton, 300 miles from his starting point.

The rest of us trotted our lightened ponies briskly over the Kootenay plains to the mouth of White Rabbit Creek. Here we occupied our old camp ground, and found that some one else had been there not long before, for a teepee had been pitched close by with only three poles, the minimum number possible. There was only one man in the outfit, as was shown by his narrow bed of boughs; and he was a white man, for his hobnailed shoes had left their imprint on the mud when he filled his kettle at the creek; and he smoked, for a tiny heart-shaped bit of tin glittered on the earth beside the dead embers of his camp fire; and he had three ponies, for three tethering pegs stood a little way off on the yellow prairie. It must have been McGavan on his way home from the most northerly tributary of the Saskatchewan, disappointed in his search for the source of the Saskatchewan placer gold. He had, very likely, pitched his lodge close to our old camp for company; and I can imagine his gloom as he smoked by the fire, little cheered by the wag of his spaniel's tail, or the homely music of the cow-bell on his grazing pony.

Once more we crossed the pass to the Clearwater, and then to the Red Deer, and as we descended to the mountain park on September 12th we at last came once more upon human beings. Below us were twenty-one lodges of white or smoked-brown canvas planted on the prairie, and a couple of squaws with faggots of dry poplar looked curiously at us from the bushes as we passed. A hundred particolored ponies grazed near by or far away, a hundred dogs barked vociferously, and almost a hundred women and children came out to watch our approach. At this reception our ponies, so unused to metropolitan life, took fright and dashed to one side, sweeping a wide curve on the yellow turf, until yelling boys and yelping curs were left far behind.

Two days later we trotted into Morley, glad that the ten days' ride of three hundred miles, over wild valleys and passes and prairie, was over.

The general physical features of the region were described in a paper read before the Canadian Institute last year, and not much need be said in addition. The valleys, with their park-like bits of meadow, and their gloomy woods of spruce and pine; the mountain flanks clothed with forest up to 7,300 feet, the summits, bare of trees, often rising into the snows and necklaced with glaciers; the tumultuous rivers, and still more headlong torrents; the gem-like, placid lakes; all unsullied by man, except where swept by his runaway slave—fire—this continued for weeks, without the sight of a human being, outside of one's own party, gives one a most vivid sense of wild and lonely majesty, of virgin solitudes unconquered and unconquerable by man.

# A CANOE TRIP ON THE SASKATCHEWAN

By L. B. Stewart, D.L.S.

About a year ago, when in discussing our proposed expedition for the coming summer to Mount Brown we decided to make a folding canvas boat a part of our equipment, it occurred to me that it would make a very pleasant termination to the trip to paddle down the Saskatchewan to Edmonton from the point crossed by our route. With this in view, I provided myself with a tracing of a portion of Palliser's map, showing the river between those two points. This proved of considerable service later on.

Early in September we commenced our return journey, having completed our explorations in the vicinity of Mount Brown, and being warned by the diminished appearance of our larder that it was time to seek civilization; and on the 9th we stopped for lunch a few miles beyond the Saskatchewan.

My proposal to paddle to Edmonton was strongly opposed by the other members of the party, but I was confirmed in my decision by the condition of our horses, whose backs were becoming very sore through our forced marches. The boat itself, from its awkward shape, was responsible for a good deal of this, and besides relieving the horses of a portion of their loads my departure would leave a saddle-horse at the disposal of the other members of the party. Being fond of boating, I looked forward to the trip with considerable pleasure, notwithstanding its loneliness.

About the middle of the afternoon we reached the Saskatchewan, which we were glad to find fordable, as on our outward journey the height of the water had necessitated a long detour to find a place where the river is confined to a single channel, which was crossed by boat, making the horses swim. After crossing, the horses were unpacked, and preparations soon made for my departure; the boat was put together and the oars converted into a double paddle; all my own belongings, and one-fourth of the provisions (there were four in the party), were put on board; and then, wishing Dr. Coleman and the others good-by, I pushed off, and in a few minutes a bend in the river hid them from view.

Owing to the lateness of the hour of starting I did not expect to travel far that day, but, nevertheless, made about twenty miles in two hours, such was the strength of the current. I was now outside of the mountains, among the so-called foothills, which would pass for mountains in any other part of the world where they were not overshadowed by their loftier neighbors. No difficulty from rapids was met with until just before camping for the night, when a spot was reached where the river narrowed to a width of about 100 feet, and rushed at a great rate against a cliff that appeared to bar its further progress, but which only caused it to make a sharp turn to the left, the water lashing itself into foam against its base. Not liking the appearance of things, I landed a short distance above and examined the rapid, but decided it could be run in safety. I made the mistake, however, of keeping too close to the shore on the left, and narrowly escaped coming to grief among some boulders, the boat striking one of these, but rebounding from its smooth surface, and soon the eddy below was reached in safety.

A couple of miles farther on, what looked like a similar rapid appeared in sight, and, as it was getting dusk, I decided to wait for daylight before attempting it, and so camped for the night.

My preparations for the night were soon made. The boat, if not affording very extensive accommodation as a tent, was a very effective shelter in case of rain, and having had supper there was nothing else to do but to retire for the night, which I did, my slumbers not being in the least disturbed by the fact that I was entirely alone.

The following morning I delayed my departure long enough to cook nearly all my provisions, so as to avoid any further delay on that account, and then, having packed up, I paddled on down the river. Shortly before noon I passed the mouth of the Ateko Sippi, a small river which enters the Saskatchewan from the southwest. At the time I mistook this river for the Clearwater, thinking a smaller stream seen farther back was the Ateko Sippi, and was disappointed the following day to find that I had only then reached the Clearwater. About three in the afternoon I passed through the gap in the outlying range of the Rockies, and for the rest of the afternoon had my attention fully occupied in guiding my boat through almost continuous rapids, and when about three hours later I was able to pause and look about me I found that the last vestige of the mountains had almost disappeared from view. The part of the river just passed through was the most dangerous met with. The danger was due not so much to the roughness of the water as the abrupt bends of the river, combined with the swiftness of the current, which made it necessary at times to strain every nerve to avoid being carried by the force of the current against the rocky cliffs, which were always met with at the sudden bends, and gain the eddy on the opposite side. I often found myself descending a rapid broadside-on, and paddling with all my strength for the side on which the eddy lay. This would be a very unsafe proceeding with the ordinary canoe, but the "Athabasca," as we called our boat, was almost non-capsizable, having a width of four feet and a length of twelve, a form but ill-adapted for speed, but admirably adapted to the work that was expected of it; speed is of very secondary importance in travelling down a river whose current averages from eight to ten miles an hour. On one occasion only was it necessary to land to empty the water out of the boat.

At 7.50 the following morning I was again under way, and at 4 p.m., as I rounded a bend of the river, the ruins of the Rocky Mountain house came in view. This was a few years ago an important trading post of the Hudson Bay Company, but having been deserted it was burnt by the prairie fires; for the country here is thinly wooded, the woodland being interspersed by patches of prairie. The chimneys are now all that remain to attest the existence at one time of this extensive and busy post; and, to judge from their number, each room of the buildings must have been provided with a fireplace, which was the practice in those days in this part of the world, where stoves were all but unknown.

About half a mile below the ruins the Clearwater River enters from the southwest. I landed here, and, having placed my property under the upturned boat, as it was raining, set out to look for a settler's house that, I had been told, was to be found about a mile up the river. I was obliged to guess on which side of the river it was situated, but I guessed aright, and in a few minutes came in sight of it. Even in the distance everything looked ominously quiet about the shanty, and I was quite prepared to find on reaching it that it was deserted. I then returned to my boat with my spirits as much damped by this discovery as my clothes were by the pelting rain, as I had hoped to replenish my stock of provisions, which was beginning to run low. I then reloaded my boat and paddled a couple of miles farther down the river.

Up to this time I had had very little time for reflection, but on this evening, as I sat beside my camp fire, with the oppressive stillness of the air broken occasionally by the distant howl of the coyote, I realized for the first time what it is to be entirely alone in a wilderness, with probably one hundred and fifty miles between myself and the next human being, and thought that if the poet who sighed "for a lodge in some vast wilderness" were only there he would be amply satisfied. Solitude certainly has its charms, which must be experienced to be appreciated, though probably a very few days would suffice for most people.

As soon as I began to stir in the morning, I was greeted by a chorus of howls from wolves, who had been tempted to come a little nearer than they otherwise would have come under cover of a mist that hung over everything; but none came near enough for a shot. Shortly after 7 o'clock I was again under way, as time was getting precious. At about 11 a huge cinnamon bear appeared walking quietly along the shore about eighty yards away. I at once picked up my rifle, but the noise made in doing so attracted his attention, and he sat down on his haunches to take a good look at the intruder. The lurching of the boat made it impossible to take a steady aim, so I exchanged the rifle for the paddle, and made for the shore, thinking he would wait, as he was taking matters so quietly, but as I was stepping ashore he beat a hasty retreat into the bushes, where I did not feel inclined to follow him. It took some days to recover from the disappointment caused by his sudden departure. In the afternoon, the current having become comparatively sluggish, and a head wind having sprung up, I decided that faster progress could be made with oars than by paddle, and landed and reconverted my paddle into a pair of oars. By 6 p.m. I reached the mouth of the Brazeau River, and camped at a spot that apparently had often served as a camp ground, judging from the number of stumps and inscriptions on blazed trees.

I hoped now to reach my destination easily in two days, but the current in the river was becoming more and more sluggish as I proceeded, and this fact, combined with the almost incessant head winds, made it impossible to do so.

The following day was spent as before, the crookedness and sluggishness of the river becoming exasperating.

The next day provisions began to look alarmingly scarce. After breakfast a piece of bread about as large as my hand, and less bacon, were all I had left, but, as I went on, the country began to show signs of the presence of man; stranded saw logs were occasionally to be seen, and here and there a deserted hut occupied some picturesque spot, and I expected soon to fall in with some lumbermen. At about 1 p.m. I heard the sound of chopping on the bank of the river, and was not long in landing and making my way to where the sound came from. I found a man working alone; his two companions, he told me, had gone down the river with a raft of timber. I was never more delighted at meeting any one; he was the only human being I had seen for nearly five days. He gave me enough provisions for a week, and I had some difficulty in preventing him giving me enough for a month. He kindly invited me to remain with him over night, probably not relishing loneliness even as much as I did, but I was in a hurry to reach Edmonton, knowing that there were only two trains a week from there, and fearing that I would be just in time to miss one, and so pushed on, having learned that there was a sawmill about twenty miles farther down the river. At 6 p.m. the mill was reached, and I was there informed that a train left Edmonton the following morning (Friday) at 7.30, and I resolved to catch that train, if possible, by rowing all night, though I had still over sixty miles to go. I rowed on until nine and then stopped and cooked some supper, and made preparations for appearing in civilization, as far as my limited wardrobe would permit, and at midnight set out again. The river at this part is comparatively placid, but occasional shoals and rapids made it necessary to be on the alert. The rapids were managed by dropping down stern foremost, thus being prepared to pull away from anything that looked dangerous. The night was beautifully clear, and a brilliant aurora afforded a certain amount of light. Shortly after seven in the morning I came across a party of miners washing for gold on a bar of the river, and on enquiring the distance to Edmonton was told that it was about fifteen miles, so I concluded that I had missed my train. As I was turning away, I heard one man make a remark to another that sounded very much like "That's a tough," which I considered very discouraging after my elaborate midnight toilet.

After a short stop for breakfast a mile or two farther I rowed on, every few miles meeting a party of miners washing for gold on the bars of the river, by which, I am told, they can earn from one to three or four dollars a day. One party I met finally told me I was only two or three miles from Edmonton, so I bestowed upon them the remainder of my provisions, and in a short time arrived at the ferry connecting Edmonton with Edmonton South, as it is called.

One of the first things I did on arriving was to telegraph to Dr. Coleman to announce my safe arrival. I had not been in town long before I met a real estate agent who pressed me to invest in town property, and showed me some advantageous sites. I did not invest, but I felt gratified to observe that everybody was not of the same opinion as my miner friends up the river. I was fortunate enough to meet several old acquaintances at Edmonton, who made my forced stay there so pleasant that it was almost with regret that I was able at last to bring it to a close, and join the rest of the party at Morley.